

Take the black magic out
of software development

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How to win the hearts
(and cash) of fickle VCs

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Mentor Graphics' recovery:
Lessons from the fall

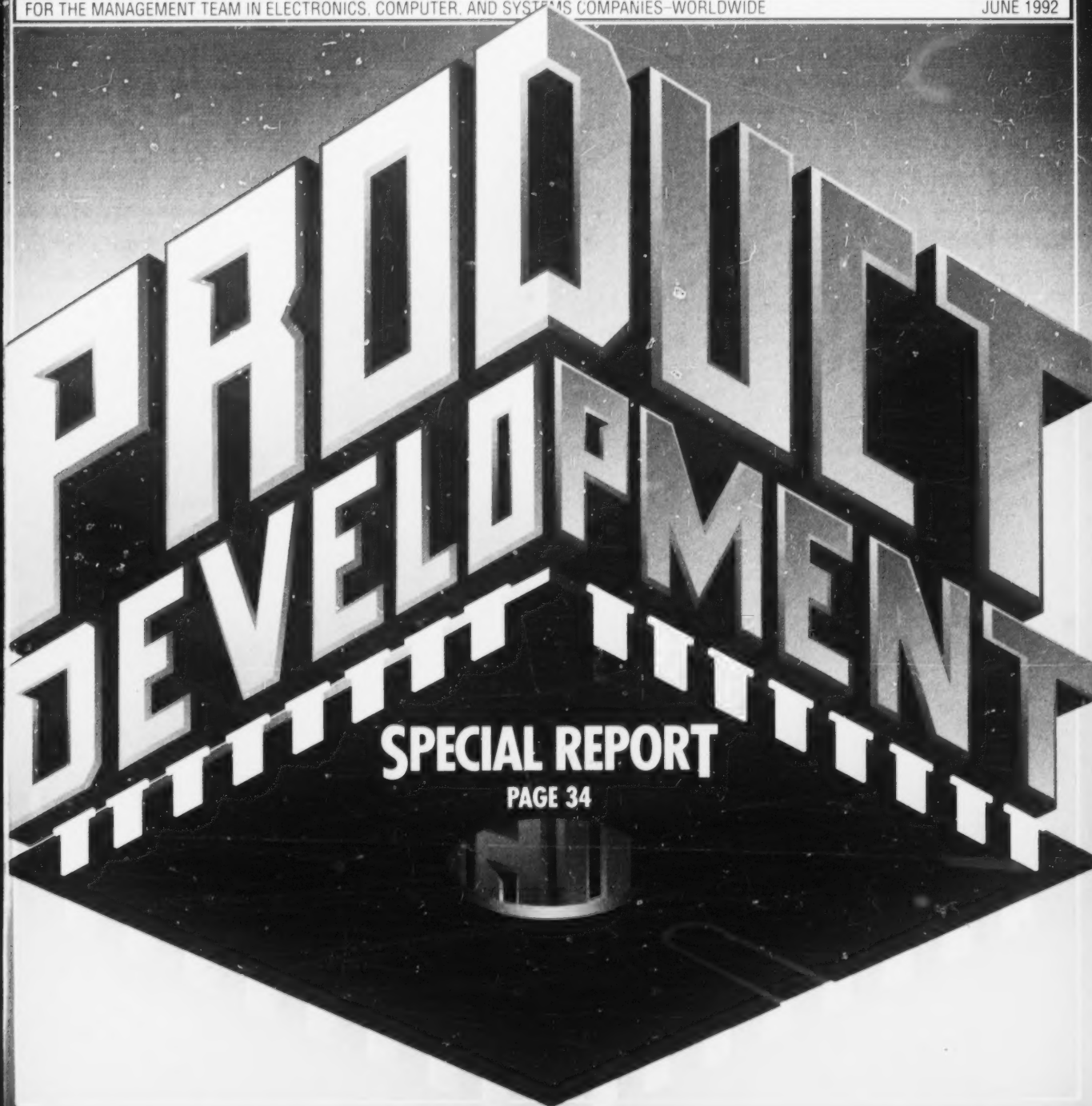
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Electronic Business[®]

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FOR THE MANAGEMENT TEAM IN ELECTRONICS, COMPUTER, AND SYSTEMS COMPANIES—WORLDWIDE

JUNE 1992



SPECIAL REPORT

PAGE 34

Electronic Business

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FOR THE MANAGEMENT TEAM IN ELECTRONICS, COMPUTER, AND SYSTEMS COMPANIES-WORLDWIDE

JUNE 1992



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PRODUCT DEVELOPMENT & MANUFACTURING

34 Take the black magic out of software development

It doesn't matter whether you consider software development to be an art or a science. What *does* matter is that you recognize the need for a structured process to help you do it better, do it on time, and do it on budget. New planning tools help you spend more time in the planning process and less time debugging

Cover illustration by Gregg Dinderman

UPFRONT

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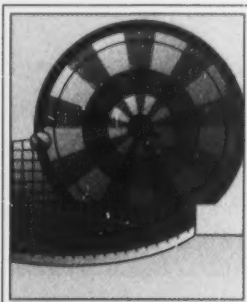
PAGE 25 Amr Mohsen, founder, chairman, and chief executive officer of Aptix Inc.

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BUSINESS STRATEGIES

High expectations foil many U.S./Asian joint ventures

MORE THAN HALF of all joint ventures and acquisitions between U.S. and Asian companies result in unfavorable profitability, poor technological exchange, and unimproved market access, according to a survey released by The Rubicon Group International.

In fact, fewer than 5% of the 110 ventures surveyed involving U.S., Japanese, Taiwanese, Singaporean, and Hong Kong companies achieved all of their objectives. Access to new markets was the most common goal, followed by growth in market share and better access to new technologies, new products, distribution channels, and management talent.

Technology companies made up more than half of those surveyed,

and there were stark differences in the success of manufacturing-driven ventures and those dependent on technology transfer, says Mark Feldman, managing director of the Orinda, Calif.-based Rubicon Group. "Commodity-oriented deals tended to do better than those that focused on R&D," Feldman says. "Things take longer to get started in R&D deals; the project gets unfocused, and people leave."

Straight manufacturing ventures get started faster and, therefore, tend to be more successful, he says. Significantly more U.S./China ventures reported more favorable results than U.S./Japan deals because of the Japanese emphasis on acquiring new technology.

Technology transfer is at the heart of most failed joint ventures, confirms Harry Sello, a Menlo Park, Calif.-based technology licensing consultant. The most common problem is the inability to manufacture an unproven technology by the partner who has purchased it in hopes of putting it into volume production. Both sides tend to point fingers at each other. "One side says, 'Your engineers weren't good enough to receive the technology,' and the other side says, 'Your teachers weren't good enough to show us how,'" says Sello. "It's often just a communication problem."

Though language barriers were not a significant factor in success or failure, personnel problems were a big factor, the study shows. Retaining key people was listed as a significant factor in acquisitions.

"In one case we found that a design engineer from the Asian company was paid 50% less than his counterpart in the U.S.," Feldman notes. "That led to a lot of friction."

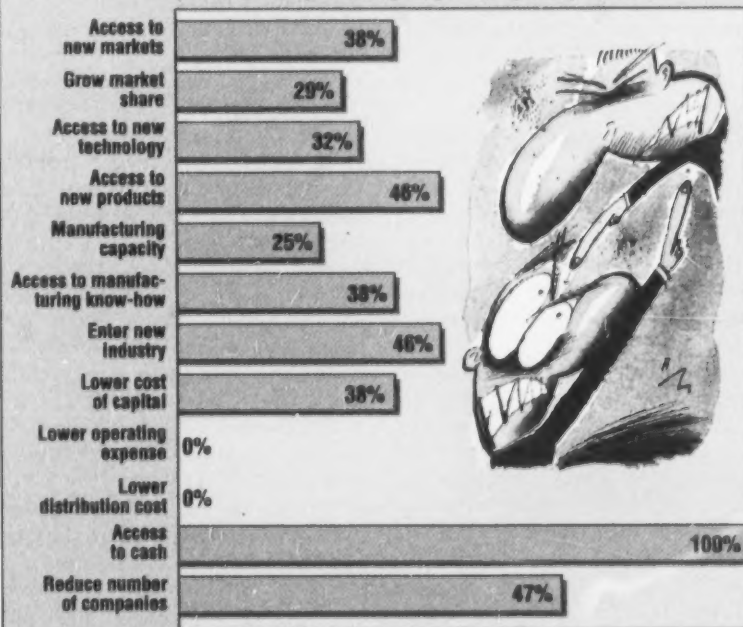
Turnover at the U.S. companies caused delays in the progress of the deals and added to the difficulty in maintaining communication.

Hidden problems associated with achieving economies of scale through the consolidation of operations and distribution included processing terminations, lost time, lost relationships, and lost knowledge.

—Hugh Willett in San Jose

Companies reporting objectives achieved

(as a % of companies targeting each objective)



PROFESSION

How engineering students rate future employers

IT'S A RECESSION and jobs are scarce, so where engineering students get the gall to rate future employers is a mystery. Still, with a nudge from *Graduate Engineer* magazine and the recruitment advertising firm Deutsch, Shea, and Evans, 1,671 engineering students from 275 colleges recently rated the nation's top employers.

Here's how the companies fared:

• Electronics engineers rated Motorola, IBM, AT&T, Intel, and Hewlett-Packard as their top five

BUSINESS TRENDS

choices. Motorola was picked by 31% of the students, lifting the company from the number-four spot in 1990 to first place this year.

- Computer science engineers overwhelming rated IBM (50%) and AT&T (34%) as their top two choices, unchanged from two years ago. Motorola, Digital, and Intel round out the top five choices. Microsoft came in sixth with only 12% choosing CEO Bill Gates for a boss.

- Students in all engineering disciplines combined rated IBM tops; 20% indicated a preference for Big Blue. Boeing, AT&T, General Electric, and Motorola were picked by another 15% to 11% of the students.

The students say they form their impressions about companies primarily from articles they read. Direct experience with a company's product or service also figures high in the students' feelings. So good press and good products, apparently, go a long way toward getting good engineers.

—E. B. Baatz

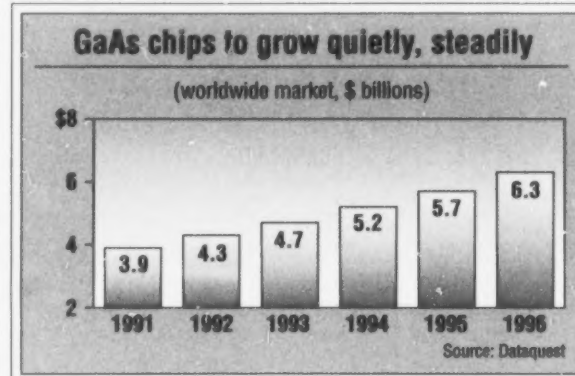
SEMICONDUCTOR MARKETS

Profits picking up at two GaAs leaders

TRACKING THE gallium arsenide (GaAs) IC market isn't all that difficult. Just two companies—Vitesse Semiconductor Corp. and TriQuint Semiconductor Inc.—account for virtually the entire U.S. merchant GaAs chip marketplace.

Recently, both companies improved their sales and profitability, suggesting that GaAs technology—known as much for its high cost as for its high speed—is about to carve out a secure, if small, piece of the semiconductor pie.

The increased sales activity of Vitesse and TriQuint will drive the U.S. GaAs IC market to \$83 million this year, or 35% greater than 1991's \$61.7 million, predicts Will Strauss, president of research firm Forward Concepts. Vitesse will fuel most of the growth, he says, because it produces digital GaAs components exclusively; about 60% of TriQuint's business comes from analog prod-



ucts, an area that is growing slower than the digital sector. A third GaAs supplier, Anadigics, produces only analog parts and has revenue of less than \$2 million.

For its second fiscal quarter, ended Mar. 30, 1992, Vitesse reported revenue of \$9.6 million and net income of \$851,000—both record levels for the company. Revenue for the first six months of fiscal 1992 totaled \$17.7 million, an increase of 71% over 1991's first half.

TriQuint, a private company, won't release its financials but was profitable in both the fourth quarter of calendar 1991 and the first quarter of this year, according to CFO Spencer Brown. Profitability occurred well ahead of the company's timetable following its merger with GaAs vendors GigaBit Logic and Gazelle Microcircuits a year ago.

TriQuint's profitability resulted from a combination of cost-cutting measures and revenue growth, Brown says. Following the merger, the company shed some excess manufacturing and cut its staff to fewer than 200 people. "Sales are now above what they were [in aggregate] prior to the merger," he says. Brown declines to comment on rumors that venture-backed TriQuint might go public this year, but notes such a move is generally the long-term goal of venture capitalists.

Although some observers speculate that captive GaAs manufacturers might eventually toss their hats into the merchant ring, Strauss downplays the possibility. U.S. companies such as Texas Instruments, AT&T, Hughes, Motorola, Rockwell,

and McDonnell Douglas all have internal GaAs programs that are tied largely to military contracts. Government-funded programs of this type can tolerate much greater production inefficiencies than are feasible in the merchant market place,

which makes it tough for the captive players to compete with Vitesse and TriQuint, Strauss says.

—Dwight B. Davis

INTERNATIONAL

Opportunities for U.S. companies in Indonesia

SMALL and midsize U.S. companies that haven't yet established a Far Eastern manufacturing base should now consider a partner in Indonesia, says a Stamford, Conn., strategic matchmaker. Here's why.

First, a recent decision by the Indonesian government to drop restrictive regulations on repatriation of profits will make it practical to keep what you earn. Another reason is a new pact protecting U.S. intellectual property rights.

But the big lure is new business. Demand for electronic components in Indonesia will reach \$2.4 billion by 1994, according to the Elsevier Advanced Technology research firm in Oxford, U.K., when sales of consumer electronics products there will reach \$398 million and demand for electronic data-processing equipment will hit \$350 million.

The country's burgeoning population, now at 180 million, is expected to boost demand for everything from electronic toys to semiconductors over the next decade. Most electronics products are imported from Japan and other Southeast Asian countries as finished goods and subject to high tariffs and import duties. The added cost puts the products out of the

BUSINESS TRENDS

FINANCE

'92 to be another boom year for electronics IPOs

EXPECT 1992 to be another good year for young electronics companies to reap cash and fame in the hot IPO marketplace, although not a repeat of last year's frenzy. Indeed, 53 companies (13 in electronics) went public during the first quarter of '92, up from 12 during the first quarter of '91. Reasonable valuations and a bullish stock market helped 38 com-

Altogether, the number of IPOs jumped 176% last year. Biotech start-ups got a big boost, up to 25 from two in the previous year, which shifted electronics' dominance. Electronics/software IPOs accounted for only 32% of total offerings, compared with 50% in 1990 and an average of 43% over the past five years.

Of the 38 electronics IPOs last year, 17 were software or service companies. The voice and data communications industry was represented by another 10 companies and only 3 computer hardware and systems companies went public in 1991.

new efforts by the CAD Framework Initiative (CFI) consortium may result in commercially available CFI-compliant tools by mid-1993.

CFI has released preliminary versions of Release 1.0., and four of its members—Sun, IBM, Hewlett-Packard, and Siemens Nixdorf—have launched pilot programs with EDA vendors to put real-life technology around CFI's paperbound specs. The IBM program, for example, will use the CFI spec for inter-tool communication to integrate its in-house framework with two commercial frameworks.

Input from these four efforts are expected to help shape a final industry-standard spec, which would be voted on in the fall and made public in December.

Meanwhile, most frameworks still don't work as promised, and CAD managers complain they spend \$2 on integration for every dollar spent on tool purchases. "We are overwhelmed by the number of tools and vendors we have to deal with," says Khanh Vu, manager of corporate CAD at Sun Microsystems Inc.

While a real framework standard could make it difficult for EDA vendors such as Cadence Design Systems and Mentor Graphics to cash in on their multi-million dollar investments in proprietary frameworks, it would be a boon for the EDA business at large—possibly a 20% increase in sales, suggests Graham. An effective standard would spur overall sales by enabling customers to spend their current integration budgets on the tools of their choice. At least that's the theory.

Buyer alert: Beware those who claim to have CFI-compliant products today. While vendors have long tried to differentiate themselves on this claim, it can't be true until the final version of Release 1.0 is made public. "Until then, anyone who says they're CFI-compliant has lost credibility," says Dan Cottrell, manager of design automation at IBM's Integration System Technology Division.

—Peter Burrows

Top 10 electronics IPOs in 1991

(% change in stock price from date of IPO to Dec. 31, 1991)

Company	Business	IPO date	Price change
Chipcom	Datacom equipment	5/1/91	158%
Quarterdeck Office Systems	Software integrator	6/1/91	133
Broderbund Software	PC software	11/1/91	109
Wellfleet Communications	LAN equipment	7/1/91	109
Xyplex	Communication servers	4/1/91	91
Artisoft	LAN equipment	9/1/91	88
Zilog	Microprocessors	2/1/91	84
Fischer Imaging	X-ray equipment	8/1/91	76
Technology Solutions	Systems integrator	9/1/91	72
Progress Software	Applications software	7/1/91	64

Source: Venture Economics

puter, software, and communications companies make their initial public offering (IPO) last year.

Oddly, the IPO boom that led 116 companies into the public arena in 1991 has some people worrying. The last time the IPO market soared this high—in 1983, when 121 companies went public—a bust followed with only 53 IPOs in '84 and 47 in '85. No doubt this bubble will eventually burst too, but several indicators suggest 1992 will be a good year for IPOs.

First, the rocky real estate market has created plenty of investment money, and the stock market continues to perform well. Another indicator is how well last year's IPOs performed in the after market—investors seem to think there are more good deals available. Moreover, the electronics industry recession seems to be ending. Semiconductor orders are up and profits are improving.

Chipcom, a data communications equipment maker in Southborough, Mass., performed the best as its initial stock price surged 158% from its IPO on May 1 to Dec. 31, 1991. Software integrator Quarterdeck Office Systems, PC software maker Broderbund Software, and LAN maker Wellfleet Communications also won big, with stock increases of over 100% from IPO date to year-end.

—E. B. Baatz

PRODUCT DEVELOPMENT

CFI pilot program promises framework tools next year

SOFTWARE frameworks are supposed to someday take the pain out of trying to make design tools from different EDA vendors work together. It hasn't happened yet, but

BUSINESS BAROMETER

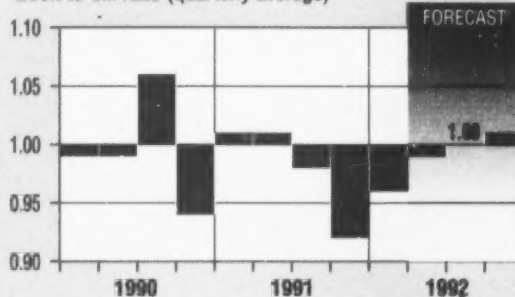
COMPUTERS AND OFFICE EQUIPMENT

Early '92 beats expectations, so forecasts revised upward

EXPECT SHIPMENTS OF computers and office equipment to now climb 8% in 1992 and 10% in 1993. This rosier outlook—compared with Cahners Economics' previous predictions of 4.2% and 6.1%, respectively—stems from the stronger-than-expected showing in the early part of this year. Shipments from U.S. factories swelled to \$19.3 billion in the first three months of 1992 (the highest quarterly total ever) and grew 9.7% above year-ago levels (the strongest gain since late 1988).

Despite this recent good news, dollar-valued sales in the next few quarters are likely to fall slightly from first-quarter levels before regaining momentum. Why? First, billings still outrace bookings. The book-to-bill ratio has stagnated below 1.00 for the past seven straight months and isn't expected to rise above parity until the third quarter of this year. Second, backlogs are extremely low and still falling. In March, backlogs dropped 9% from year-ago levels to \$9.92 billion—as low as they've been in 14 years. Third, stockpiles are low, too. Inventories shrank 8.7% from March 1991 to March 1992, falling to \$9.87 billion.

Book-to-bill ratio (quarterly average)



(\$ billions)

	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1
Orders	17.6	16.8	17.0	18.5	18.7	18.9	19.3	21.1
Shipments	17.5	17.1	18.4	19.3	18.9	18.9	19.2	20.6

Source: Commerce Dept.; Forecast: Cahners Economics

Yes, manufacturers have been slashing as a matter of policy in order to reduce costs and boost balance sheets. With the house cleaning just about completed, computer and office equipment vendors will have to slow shipments growth, until underlying demand from consumers and businesses catches up.

—Madeline Franchi

COMMUNICATION EQUIPMENT

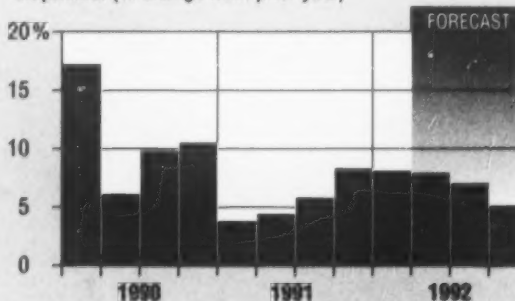
Blessed with bloated backlogs, this industry is looking up

THE COMMUNICATION EQUIPMENT industry beat the averages in 1991 and will continue to do so as Cahners Economics predicts shipments will increase 7% in 1992 and 9% in 1993. Unlike the computer and office equipment sector, which watched shipments retreat 1.4% in 1991, communication equipment company executives enjoyed a 5.6% advance in factory shipments last year. Solid, if not stellar, growth continued into 1992 as first-quarter shipments climbed 8.1% from the year-earlier period and 1.3% from fourth-quarter 1991 levels.

Furthermore, these forecasts hold a good dose of upside possibility because this industry, again unlike the computer industry, is blessed with bloated backlogs. At the end of March 1992, unfilled orders totalled \$19.7 billion. Although down 9% from a year ago, communication equipment backlogs now stand 4.4 times higher than March shipments (compared with backlogs that are only 1.6 times shipments in the computer industry).

Adding to the industry's optimism, demand for communication equipment is clearly recuperating early

Shipments (% change from prior year)



(\$ billions)

	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1
Orders	11.3	11.5	13.0	13.1	13.4	13.3	13.7	13.7
Shipments	12.2	12.5	13.0	13.2	13.1	13.4	13.7	14.0

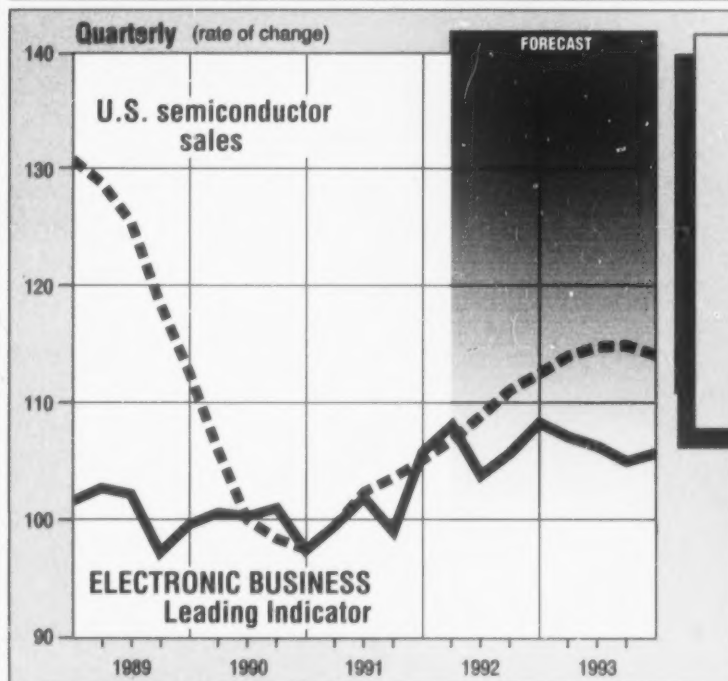
Source: Commerce Dept.; Forecast: Cahners Economics

from the recession. After posting a 2.1% loss in 1991, orders popped up 14.2% from year-ago levels in the first three months of this year. Although orders are often volatile from quarter-to-quarter, this resurgence is the real thing. Survey data from the Commerce Department business investment in communication equipment confirm the trend.

—M. F.

BUSINESS BAROMETER

ELECTRONIC BUSINESS Leading Indicator

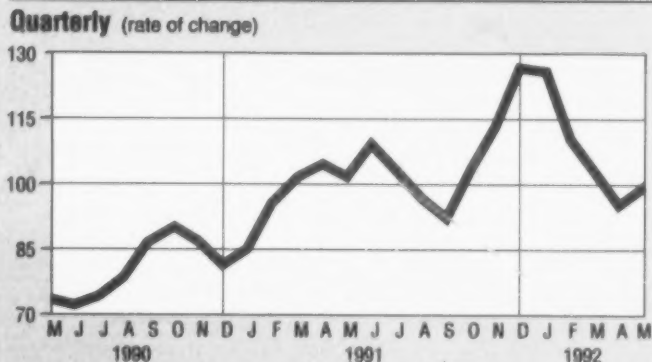


Indicator hits snag in April, temporarily

WHEN THE ELECTRONIC BUSINESS Leading Indicator (EBLI) weakened from 106.7 in March to 102.9 in April, everyone worried about a repeat of last year's aborted recovery, which was recorded by an upward swing to a two-year "peak" of 103.3 in April 1991 and a subsequent mild retreat. However, since the EBLI is based on year-over-year growth, this drop-off is not a dire sign. The EBLI is still on track. Unlike 1991, it is expected to push forward to its next peak of 109.4 in December. The modest recovery moves onward slowly.

—John Farrell

Purchasing's delivery times show erratic trend



	Latest month	Previous month	Year ago	1990 average
ELECTRONIC BUSINESS Leading Indicator (rate of change, Apr.)	102.9	106.7	103.3	101.6
U.S. semiconductor bookings (\$ millions, 3-month average, Apr.)	\$1,570	\$1,528	\$1,468	\$1,311
Weekly hours of semiconductor production workers (monthly average, Mar.)	42.9	42.7	41.1	41.1
Electronic components lead time index (1977 = 100, May)	83.7	81.8	93.3	87.5
S&P's semiconductor stock price index (1970 = 10, monthly average, Apr.)	82.1	88.0	74.8	68.5
Change in electronic components inventories (\$ millions, SA, Mar.)	-\$35	\$73	\$19	-\$53
Contracts and orders for plant and equipment (\$ billions, SA, Mar.)	\$37.0	\$35.4	\$35.9	\$35.0

SA = seasonally adjusted; all other data are not seasonally adjusted

Sources: Semiconductor Industry Association, Bureau of Labor Statistics, Electronics Purchasing magazine, Standard & Poor's, Commerce Dept., Bureau of Economic Analysis, Cahners Economics



Take the **BLACK MAGIC** out of SOFTWARE DEVELOPMENT

As in hardware, a structured process will produce better software, on time and on budget. Here's how

By Rick Whiting

Is software development an art or a process? Ask a dozen people in the computer industry and you'll get a dozen different answers, but nearly all agree on one point: *Managing* software development is a process.

It's also a process more managers are being forced to learn as hardware becomes a commodity and software accounts for an increasing percentage of product value. Often, those charged with overseeing product development find themselves on unfamiliar ground.

Here's the problem: While there are just so many ways to design a computer or lay out a printed circuit board, there are an almost infinite number of ways to write a computer program. The steps for developing software are not as clearly defined as with hardware, and

benchmarks for measuring product quality and development process efficiency are rare.

All this can make managing software a nightmare for product development chiefs, many of whom have hardware engineering backgrounds. "Engineering managers feel that they are losing control of the development process," says Louis J. Mazzuchelli Jr., chief technical officer at Cadre Technologies Inc., a Providence, R.I., vendor of computer-aided software engineering (CASE) tools. "There's a lot more ambiguity on the software side. There are no ground rules."

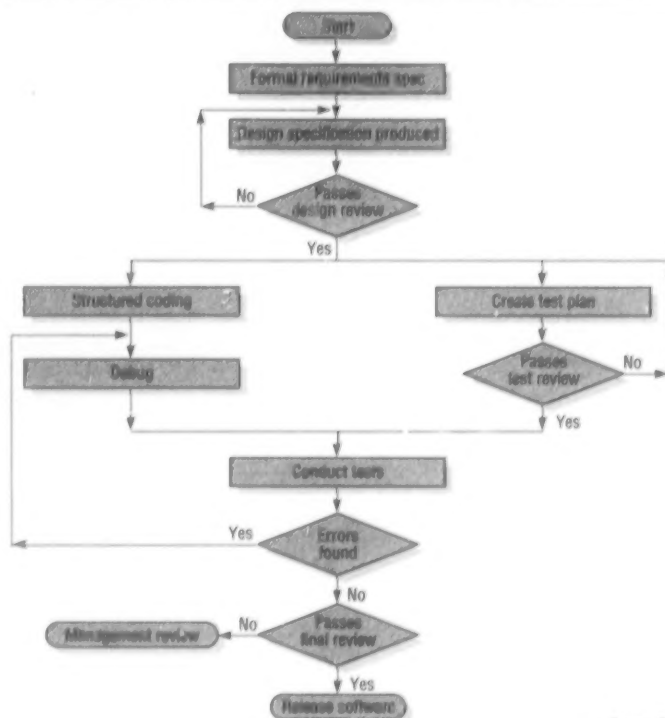
The result: Software development projects frequently run far behind schedule and over budget. Cost overruns for even small projects average \$100,000 and can reach \$3 million to \$6 million for large-scale efforts, says T. Capers Jones, chairman of Software Productivity Research Inc. (SPR), a Burlington, Mass.-based software consulting firm whose clients include AT&T, Hewlett-Packard, and Digital Equipment Corp. Many projects never see the light of day. Jones calculates that canceled projects consume about 15% of all software development efforts in the U.S. each year, costing some \$14.3 billion and a loss of over 285,000 person-years in programming time.

It seems clear that software development remains a mysterious sink-hole for cash and effort for most companies used to developing only hardware. That must change, and fast, as the absolute value of hardware declines. For some companies, it will mean dumping all hardware. For most, it will mean creating a mix of value in hardware and software. Consider the following examples:

Epoch Systems Inc. once built proprietary storage servers to run its software but now just assembles servers from SPARC boards purchased from Sun Microsystems Inc. The Westborough, Mass., company has even begun selling its network data management software without any hardware at all. Marketing vice president Kent Godfrey estimates that 60% of the company's gross margin is earned from software—a figure reflected in the fact that 37 of the company's 40 engineers are software programmers and the company has done no real hardware development for three years.

Xylogics Inc. has evolved from a manufacturer of peripheral controller boards to a builder of communications servers and other products. Software today accounts for about 70% of the "value-add" of Xylogics's products, CEO and president Bruce Bergman says, and the Burlington, Mass., company has plans to sell unbundled software. "In just two years

How to structure your software development



Source: PRISM

we've migrated pretty dramatically," says Bergman. "Software development has always been more difficult to manage. We've done a reasonably good job, but it's hard to get your hands on."

Veritas Software Corp. of Santa Clara, Calif., has made a complete metamorphosis. Originally named Tolerant Systems Inc. in the 1980s, the company manufactured fault-tolerant computer systems before concluding that its real market value was its storage management and quality testing software. When it jettisoned its hardware products in favor of software, "It was a major earthquake of a change in the business," says Mark Leslie, then on the company's board and today president and CEO of Veritas. Of the company's original 45 employees, only a handful remain.

The change from developing hardware to devoting at least an equal effort to software need not be gut-wrenching. "I think that we treat software and hardware development much the same. The tools, terminology, and metrics may be different, but the management issues are the same," says Shelly Lowenthal, AIX systems division engineering director at Cambex Corp., a Waltham, Mass., developer of data storage hardware and software.

PRODUCT DEVELOPMENT & MANUFACTURING

Experienced managers say those issues include more effort at the start to clearly define the features of a new product; a tracking methodology to keep projects on schedule and within specifications; a testing process and other techniques to ensure product quality;

and strategies for obtaining customer input and incorporating that data into new products.

The effect of adopting a structured approach can be dramatic. As much as 50% to 60% of the time needed to

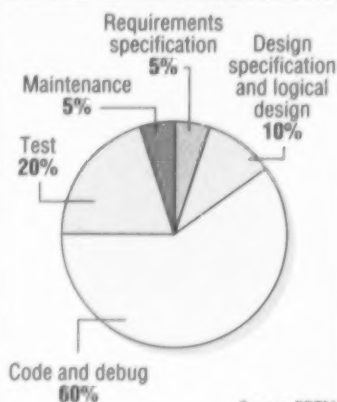
Commercially available tools for planning and tracking software development have been lacking in the past. Jones says, however, that as many as 75 planning tools for project management and 45 automated estimating tools—expert systems used to calculate the resources a development project will need—will be on the market by the end of this year. "Failure to use automated estimating and planning tools for large systems is management malpractice," Jones writes in a draft of a book he is writing on software development problems.

Although most problems are revealed in the late stages of a project, their causes usually can be traced back to failures in the early product development phases. "You'd be surprised at the number of companies that throw a bunch of engineers into a room, give them a project, and let them go at it," says Edward A. Taylor,

president of PenCom Software in Austin, which provides software development services to such companies as IBM, Sun Microsystems, and Advanced Micro Devices.

Common problems, says PRTM's McGrath, include ambiguities in product definition, omissions in specifications, and incom-

How developers think they spend their time

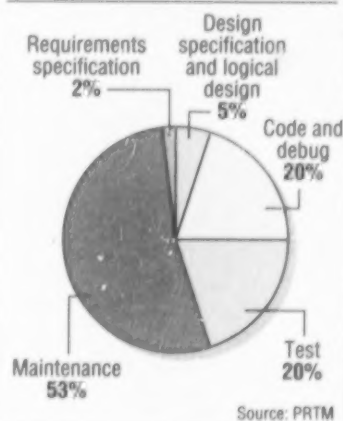


develop new software products can be eliminated by instituting a structured development process, "something which most companies don't do," says Mike McGrath, a managing director of the Pittiglio Rabin Todd & McGrath management consulting firm in Weston, Mass.

Epoch, for example, divides its development process into product requirement, design, coding, and internal and external testing phases. Each phase is made up of a half-dozen to a dozen steps, and projects are reviewed before moving on to the next phase. At the end of the product requirements phase, the decision is made whether to fund the project following a review by the company's executive board and finance and marketing representatives.

Overseeing the process should be a core or cross-functional team of representatives from a company's various departments, including software engineering, marketing, quality, customer service, documentation, and operations. For a new communications server product under development at Xylogics, a core team conducted customer interviews, drew up the product's specifications, and is now overseeing the development work.

How developers actually spend their time

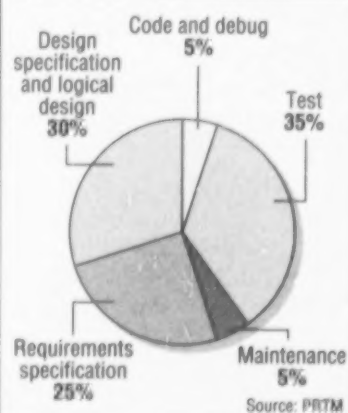


patible interfaces between software modules and between software and hardware.

Requirements specification, the phase in which a new software product's functionality and target market are defined, should account for about 25% of the total development process,

says McGrath. Design specification and logical design, when a detailed product blueprint is drawn up and development schedules are prepared, should account for another 30%. Only 5% of the process should be devoted to actual

How developers should spend their time



Software today: Late, over budget, and full of bugs

JUST HOW SERIOUS are the problems with software development in the U.S.?

Fifty percent of all software projects that are larger than 1,000 function points run over budget, according to Software Productivity Research Inc. chairman T. Capers Jones, who conducts surveys of the software industry. He estimates cost overruns average \$100,000 for projects of 1,000 function points and as much as \$3 million to \$6 million on projects of 10,000 function points.

Function points are catching on as a means of quantifying software. A car fuel injection system, for example, contains between 150 and 600 function points. Software for a PBX system is made up of 1,000 to 5,000 function points, while an operating system has as many as 25,000 to 60,000 function points.

Predictably, larger software projects contained more bugs. Alarming, however, Jones found the efficiency rate for correcting those bugs before the software reached

the market decreased as the size of the project increased. A relatively simple program with 160 function points, on average, has 500 bugs, 92% of which will be removed before the product hits the market. For a huge project of 40,960 function points, such as an operating system or airline reservation program, only 63% of the potential 250,000 defects will be caught.

Even worse is the time and resources lost on software projects that are ultimately canceled because the product never achieved its intended performance or because the project took too long and the market opportunity was missed.

Canceled software projects, on average, run a year behind schedule and are twice their budget by the time they are killed, Jones's surveys discovered. Canceled projects consume about 15% of all software development efforts each year, costing some \$14.3 billion and wasting over 285,000 person-years in programming time. □

coding and debugging, McGrath says.

Too often, no one tells this to the programmers. PRTM estimates that most companies spend only 2% of the development process on requirements specification and only 5% on design specification and logical design, while coding and debugging chews up 20% of the process. New product testing should account for 35% of the process instead of the 20% most companies devote to it. The result is that the average company spends 53% of its development time and resources on maintenance instead of the 5% it should take.

Some companies are adding rapid prototyping to the early stages of their development work. By building a scaled-down version of a new product, Veritas engineers learn how long the final product will take to build and what resources it will require. CEO Leslie says the company has even dumped projects after what he calls the "concept exploration" phase. Prototyping also provides a way to try out

different approaches or designs to resolve problems.

"The more time you spend up front doing design specifications, the more time you spend with customers, and the more time you spend on prototyping, the more successful your software package will be," says Gary J. Stump, a senior consultant with Technology Edge, a



"Software development has always been more difficult to manage [than hardware]," says Xylogics's CEO Bruce Bergman (right) shown with engineering vice president Bruce Sachs

Dana Bradley

Software for customers —not programmers

KNOWING WHAT the customer wants in a new software product is the first step in software development.

"When you're building hardware, you really don't need to be that close to the customer's needs. You only need to build a product that is competitive in price/performance," says Gary J. Stump, a senior consultant with Technology Edge, a Boise, Idaho, consulting firm. That won't cut it in software where products must be particularly tailored to customer needs.

Sending engineers to meet with intended customers is the most basic idea. Companies "need to get their development staffs out with customers so that their engineers become sensitized to customer needs," Stump says. That should occur during the early planning stages for a new product and when developers have a working model. "The best thing you can do is go back to the customer and hear him say: 'No, that's not what I wanted.' That's defect removal at an early stage," Stump adds.

Companies can also bring the customers to them by bringing on board advisers with expertise in the target market: a chemist, for example, to help oversee development of software for chemists. "You need someone who speaks customer-ese," Stump says. "They keep everyone honest."

Veritas Software Corp., a Santa Clara, Calif. hardware-turned-software company, has customers on a panel that examines product ideas during a "concept review" stage—before coding work begins. Currently, a Wall Street trading firm executive is among those providing input for new products.

Xylogics Inc., a Burlington, Mass., vendor of communication servers and controllers, keeps close ties with such leading-edge customers as NASA and universities. The assumption is that product features they want today will be in general demand tomorrow.

By reducing the need for redesigns and other cleanup work, collecting customer data and developing a market requirements document for a new software product can cut a project's development time by 30% to 40% and its cost by 50%, says Jeff Schlageter, engineering vice president at Actel Corp. in Sunnyvale, Calif. □

Boise, Idaho, management consulting firm.

Still, given that many consider programming to be an art, there is always the danger of bringing *too much* structure to software development. The same process and metrics that support weaker employees can prove stifling to superstar programmers, says Dan Rourke, a senior programmer with IBM's personal systems programming operation in Austin. "It's important to maintain the creativity and innovation that we want to see," he says.

Quality and test assurance is another hurdle

Core team at the center of software development

Core team members overseeing software development represent all segments of a company



Source: PRTM

that companies frequently trip over. "Most hardware companies believe they can test software the same way they can hardware," Stump says. While hardware can be checked by running it non-stop for weeks, there is no way to test software for every circumstance. Bugs may crop up only under certain conditions and are often not discovered until long after the software has been released, says T. Michael Nevens, a principal with the McKinsey & Co. consulting firm.

Correcting a bug in a product that's already shipped can cost from \$5,000 to \$25,000, depending on the code complexity and the size of the installed base, estimates Veritas's Leslie.

SPR's Jones says that quality assurance should be separate from the rest of the development organization and should have its own chain of command and the power to halt a project. Rather than play a passive observer role, a quality assurance department should aggressively collect and analyze defect data, develop and run test programs, and teach courses on

How to tell if you're developing quality software

SOFTWARE DEVELOPMENT is a young field and, at best, an inexact science. As a result, few industry-standard tools, methodologies, and metrics exist for measuring product quality and process improvement.

"The biggest problem with software is that you never really know where you're at," says Fred Molinari, president of Data Translation Inc., a Marlborough, Mass., supplier of data acquisition software and boards.

Managers, consultants, and assorted industry gurus disagree over how to measure software *quantity*. Lines of code can be deceiving since one programmer can solve with 10 lines of code a problem that may take another programmer 25 lines. That makes bugs-per-line of code an imprecise measure of product and process quality. Even the definition of "bug" is murky: If a program freezes when a user makes a wrong keystroke, is that a defect?

More managers are turning to function points as a more definitive way of measuring software. Function points are made up of a weighted combination of inputs, outputs, inquiries, logical files, and interfaces that describe a software program's features. A computer-aided design tool may contain 600 to 2,500 function points, for example, while an operating system may have 25,000 to 60,000 function points.

Industry-leading software has an average of .02 defects per function point, estimates

T. Capers Jones, chairman of Software Productivity Research Inc. in Burlington, Mass. Jones says that while such companies as Hewlett-Packard Co., AT&T, and IBM are approaching that level, most software with bug counts that low are found in advanced weapons systems such as Raytheon Co.'s Patriot missile. Jones believes that the industry average for software defects is in the range of 0.2 or 0.3 per function point.

Given the inherent ambiguities in software, managers are putting more emphasis on trend analysis—in effect, comparing a company's development process efficiency or product quality with itself.

For example, Arthur Zachai, a senior consultant with Arthur D. Little Inc., suggests tracking how many changes are made in code that has already been written. "It's a very powerful, simple metric," he says. If a program has 1,000 lines of code and 100 lines are being changed every week, "you're nowhere near having a product for release."

Other useful trend-analysis metrics include the number of defects discovered per 100 hours of testing and the number of defects per root cause—bugs traced to a specific problem such as poor feature specification or interface definition.

An increasing number of companies are adopting a methodology created by the Software Engineering Institute at Carnegie Mellon University to assess how their software development procedure stands up. □

How does your software development measure up?

Example	Project size in function points	Length of project (months)	Number of programmers	Project cost (\$ millions)	Potential # defects	% defects removed before released
Car fuel injection system	160	9	2	95	500	92
Simple word processor	640	16	10	800*	2.2*	85
Advanced spreadsheet, PBX	2,560	29	45	6.5	10.2*	79
CASE tool, insurance claim program	10,240	53	200	52.5	51*	72
Operating system, airline reservat'on system	40,960	96	900	430	250*	63

*Thousands

Source: Software Productivity Research

PRODUCT DEVELOPMENT & MANUFACTURING

Where the programmers are

Software developers and their managers by country in 1990

Country	Programmers	Managers	Total
USA	1,693,200	253,980	1,947,180
USSR	1,445,000	216,750	1,661,750
India	1,252,500	187,875	1,440,375
China	990,000	148,500	1,138,500
Japan	850,000	127,500	977,500
Germany	505,600	75,840	581,440
Indonesia	460,000	69,000	529,000
Brazil	441,000	66,150	507,150
England	370,550	55,575	426,075
Italy	365,400	54,810	420,210
France	364,000	54,610	418,600
Mexico	261,000	39,150	300,150
South Korea	236,500	34,475	271,975
Spain	234,000	35,100	269,100
Thailand	196,000	29,400	225,400
Turkey	192,500	28,875	221,375
Poland	190,000	28,500	218,500
Canada	169,000	25,350	194,350
Egypt	137,500	20,625	158,125
Taiwan	116,000	17,400	133,400
Total	10,469,700	1,567,465	12,040,155

Source: Software Productivity Research

quality improvement, Jones says.

Xylogics has split its quality assurance operation off from the development group to allow programmers more time to concentrate on new products, says engineering vice president Bruce I. Sachs. Veritas takes the opposite stance and has no quality assurance department, opting instead to make each development group responsible for the quality of its own work.

As with planning tools, commercially available tools to test new software products are scarce, and most companies use test programs developed in-house. The good news is that more bug-remover software is becoming available. Veritas, for example, received so many requests for its Vista test program that the company has put the product on the market.

If a project is relatively small in scope, hardware and software development teams should work closely together—if not physically side by side—with representatives of each sitting on the other's core team. For large projects, where hundreds of engineers may be involved, the hardware-software interface should be defined and documented early in the specification and design phases. And hardware prototypes built early in the process allow hardware and software to be tested together sooner.

McKinsey's Nevens says the increased use

of networked workstations by hardware and software engineers is improving inter-team communications and reducing the number of end-of-the-process snafus that usually plague development projects.

Software programmers in the past have been the poor relatives among engineering disciplines in terms of capital investment. SPR's Jones estimates that the average electrical or mechanical engineer may have as much as \$200,000 worth of computers, software, and other equipment at his or her disposal—a far cry from the \$20,000 or so that Jones says that software engineers have.

Nevens believes that is changing as workstations become cheaper and more software development tools become available.

"People are beginning to understand that you have to have the capital investment behind the programmer to make him truly productive," he says.

Leading-edge companies are also adopting object-oriented programming (OOP) technology to boost development process efficiency and product quality. Using OOP, a developer can "encapsulate" bits of software code and reuse them to assemble new programs rather than write each program from scratch. Actel Corp., in Sunnyvale, Calif., has seen programmer productivity improve by 50% by using C++, an object-oriented programming language, according to architecture staff engineer Telle Whitney.

OOP also has a subtle benefit for hardware companies wrestling with software. Because OOP uses pieces of software as components from which to assemble new products, the technique follows more closely the way hardware engineers traditionally think.

Don't be misled. CASE, OOP, and other tools will fail unless used as part of a process. Managers often fall into the trap of thinking that CASE tools are silver bullets to solve all of their development problems.

"A fool with a tool is still a fool," says Anthony I. Wasserman, president of CASE software supplier Interactive Development Environments Inc. in San Francisco. □



How does your software operation stack up? (Probably lousy)

A system for grading and improving the process promises to help you smooth out those software development lumps

By Peter Burrows

One key problem for software developers is knowing how their process rates against the state of the art. There's simply been no objective tool by which engineers could grade, or even describe, the largely subjective task of generating a new program.

There still is no such tool, but the Software Engineering Institute (SEI) at Carnegie Mellon University in Pittsburgh is establishing itself as a starting point. Consisting of a rudimentary software maturity model that segments the discipline into five "grades" of proficiency and a process-improvement process designed to bring hardware-style discipline to the "art" of software engineering (see chart), the SEI offers a system to help companies find where they are and where they must go.

"It provides a very articulate way to isolate your strengths and weaknesses and helps you focus less on your people and more on your processes," says Ronald Madsen, U.S. software process improvement program manager for Digital Equipment Corp. "It is becoming the de facto model to describe good software engineering practices."

Some warn that the SEI tool could be used not as a software-development aid but as an arbitrary weapon. Others argue that it offers trivial answers to complex problems. Advocates point out, however, that its purpose is not to give answers at all; rather, it provides a framework to ensure that solid engineering practices are being followed within the software organization. Using the SEI system does not, for example,

preclude engineering management from implementing computer-aided software engineering (CASE) tools or object-oriented programming—it just requires that they be used in a controlled, well-managed manner.

Here's how it works. Interested companies either assess themselves or bring in one of the nine consultancies licensed by the SEI (see

SEI's software report card		
Maturity level	Selected characteristics	% of U.S. companies (based on 1990 survey of 55 projects)
Level 5 "Optimized"	- Improvements fed back into process - Automated data gathering - Rigorous defect-cause analysis and defect prevention	0%
Level 4 "Managed"	- Measured process - Some quality and productivity measurements - Established process database with resources to analyze and maintain data	0%
Level 3 "Defined"	- Defined and institutionalized process - Established Software Engineering Process Group	4%
Level 2 "Repeatable"	- Process dependent on individuals - Basic project controls - Good at incremental change; bad at major change - No orderly framework for improvement	22%
Level 1 "Initial"	- No formal procedures, cost estimates, or project plans - Few controls, little tool integration - Little senior management input	74%

Source: Software Engineering Institute

SEI's software improvement process

Step	Time
Get management's commitment	Indefinite
Prepare for process improvement program:	2-10 months
• Choose SEI-licensed assessor or in-house team • Determine group to be assessed • Create a process improvement team	
Conduct assessment:	1 week
• Hold opening meeting with management and participants • Interview project leaders, functional area representatives and other participants • Hold other discussions as appropriate • Review preliminary findings with project leader and other participants • Present findings to management and all participants	
Develop report with recommendations for attacking priority areas for improvement	1-2 months
Develop action plan that accounts for:	6-12 months
• Resource allocation • Scheduling • Responsibility delegation • Management review process	
Improve	Expect 2-4 years to go from Level 1 to Level 2
• Implement quantitative process management • Fill in gaps in training • Move toward software-engineering discipline	1-3 years to Level 3 1-3 years to Level 4 1-3 years to Level 5
Reassess	Every 1 1/2 years

Source: Watts Humphrey, founder of SEI's software process program

chart). The assessment, which includes questionnaires and a week of interviews with managers and software developers, tells the company which of the five categories it fits into and what its key problems are. Working either with the consultant or alone, the company sets up a process-improvement team and uses SEI guidelines to attack problem areas.

The process is expensive up-front—assessors usually charge about \$40,000 per organization and the improvement process typically requires large investments in time and manpower. Also, expect progress to be slow. To go from Level 1 to Level 5—which no company has done so far—would take about 10 years, says Humphrey.

But success does come to those who wait. Hughes Aircraft says it spent \$45,000 on an assessment and \$400,000 on a two-year improvement program but ultimately saved about \$2 million in time-to-market savings, reduced costs, and improved employee morale.

Why has the SEI risen to the fore?

First, it is fully funded by the world's largest software user, the Department of Defense, which formed the SEI in 1984 after studies showed that only a fraction of its software projects were coming in on time and on budget. Also, the SEI represents one of the more impressive collections of software experience outside of proprietary R&D labs. Of its 168 technical staffers, 74% came from industry and more than 44% have at least 20 years' experience.

In all, the SEI and its consultants have performed about 80 assessments. This includes only a handful of commercial outfits, but interest is on the rise at companies such as DEC, IBM, Motorola, Unisys, and others, which are increasingly using it as a tool to extend their total quality management programs to the software realm.

While the SEI system was designed to be used in such a spirit of self-improvement, interest is also being driven by other motives. For one, the European Community (EC) has published guidelines as part of its ISO-9000 regulations that require software companies to have strictly defined quality systems in place in order to sell software in the EC. Many electronics companies, most of whose software operations lack the quality systems that enabled them to comply with ISO-9000 directives

for certain classes of hardware, see the SEI system as a tool to satisfy the requirement.

For more information on the SEI, call (412) 268-6257. □

Third-party assessors licensed by SEI

- American Management Systems Inc.**, San Diego, Calif. (619) 297-5800
- Arthur D. Little Inc.**, Burlington, Mass. (617) 272-1770
- Dayton Aerospace Associates Inc.**, Beavercreek, Ohio (513) 426-4300
- Digital Equipment Corp.**, Englewood, Colo. (303) 649-3484
- Pragma Systems Corp.**, Falls Church, Virginia (703) 560-4669
- Software Productivity Consortium**, Herndon, Virginia (703) 742-7216
- Process Inc.**, Kingston, Ontario (613) 531-9972
- Technology Applications Inc.**, Alexandria, Virginia (703) 461-2053
- The Process Enhancement Partnership**, Silver Springs, Maryland (301) 587-1315



39% of companies use a formal product development protocol

That's the good news. Sadly, almost as many companies don't, and they have no plans to do so soon

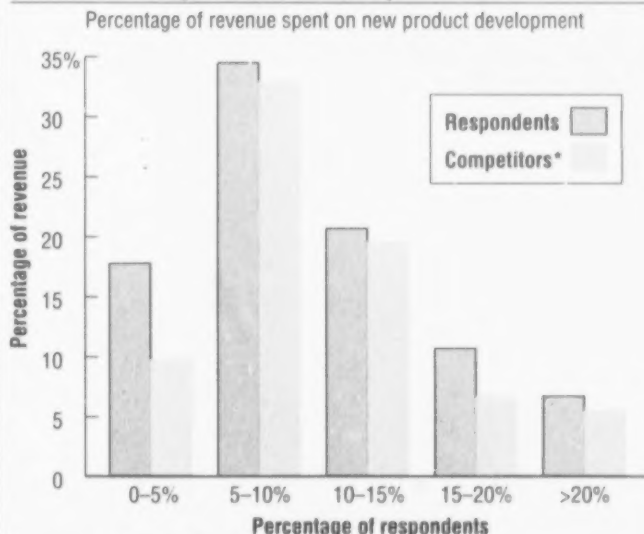
How important is new product development to your company's success? The obvious answer, of course, is that it's vital. *ELECTRONIC BUSINESS* has long wanted to understand in more detail how companies perceive and pursue this important activity and to what extent they rely on supplier partnerships in the process. When DuPont Electronics suggested that we jointly conduct a survey to learn the answers, we jumped at the chance. The results are revealing and often startling. For example, U.S. manufacturers still prefer Japanese partners for quality. That's alarming.

Here's a quick look at the demographics. We

surveyed 254 companies, 38.6% of which generated more than \$1 billion in annual revenue. Another 13.4% represented companies generating between \$250 million and \$1 billion in revenue, and the remaining companies represented those that had less than \$250 million. More than a quarter of the respondents were computer companies; 13% were semiconductor manufacturers; 12.6% were communications companies; and the rest represented the automotive, consumer, military, industrial control, and test and instrumentation segments.

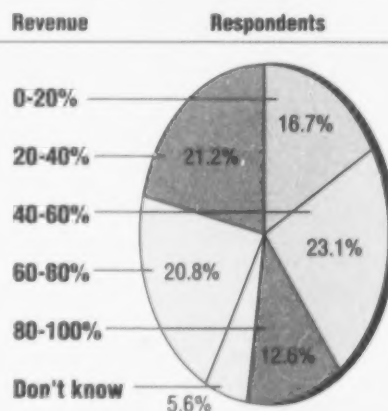
We hope this snapshot of how your colleagues and competitors approach product development provides fodder for your planning process.

How much do you spend on product development?



*Respondents' perception of competitors' spending

What percentage of your company revenue is from products developed in the last 3 years?



Source: *ELECTRONIC BUSINESS* and DuPont

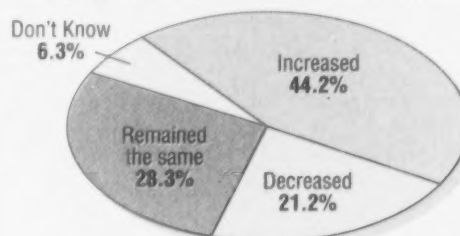
PRODUCT DEVELOPMENT & MANUFACTURING

IT'S HARDLY A SURPRISE that virtually all respondents to the joint ELECTRONIC BUSINESS-DuPont survey report that new product development is critical to their success. Not only are companies spending more on product development than in the past—and receiving greater returns—but also respondents say that they are under greater pressure to develop new products faster and with higher quality than ever before. Having acknowledged that, it's worth noting that more than a third of the respondents do not have a formal product development process. Thirty-nine percent have structured protocols, and the remainder report using partially implemented protocols.

There seems to be growing acceptance of the fact that no company can go it alone and succeed. To that end, manufacturers throughout

Companies are spending more on development

How has your company's percentage of revenue spent on new product development changed versus 5 years ago?



Source: ELECTRONIC BUSINESS and DuPont

the electronic food chain expect to include their suppliers in the product development process. Conversely, although manufacturers report they want to involve suppliers more deeply in the design process, they also remain willing to dump suppliers for a small price difference. □

Why companies partner with suppliers

Top partnering benefit by supplier category

	Materials	Components	Board subsystems	Contract manufacturing
Lower total cost	59.1	55.8	45.4	54.4
Shorter time-to-market	40.4	51.5	49.2	46.8
Better quality	40.4	32.0	31.1	20.3
Minimize capital investment	24.9	18.0	25.1	40.5
Other	22.7	30.5	21.8	19.6
N/A	0.0	0.0	1.1	1.3

Multiple responses allowed; % respondents

Source: ELECTRONIC BUSINESS and DuPont

Japan still wins on quality

What are the advantages of partnering with U.S. and Japanese suppliers
(% of respondents)

Japan/U.S.	Materials	Components	Board subsystems	Contract manufacturing
Product quality	71.5/35.9	67.7/28.4	63.4/24.4	59.5/25.8
New product leadership	39.2/24.3	44.9/31.6	31.7/27.9	18.9/16.4
Pricing	38.6/19.4	40.7/18.6	39.0/21.5	43.2/24.5
Ease of communications	0/31.1	0/29.3	0/27.9	0/32.1
Cycle-time responsiveness	8.2/16.0	9.0/14.4	11.4/21.5	12.6/31.4
Technical support	13.9/30.6	10.8/37.7	17.1/31.4	11.7/23.9
Openness and trust	1.9/5.3	1.2/5.6	2.4/6.4	4.5/7.5

Multiple responses allowed

Source: ELECTRONIC BUSINESS and DuPont

PRODUCT DEVELOPMENT & MANUFACTURING

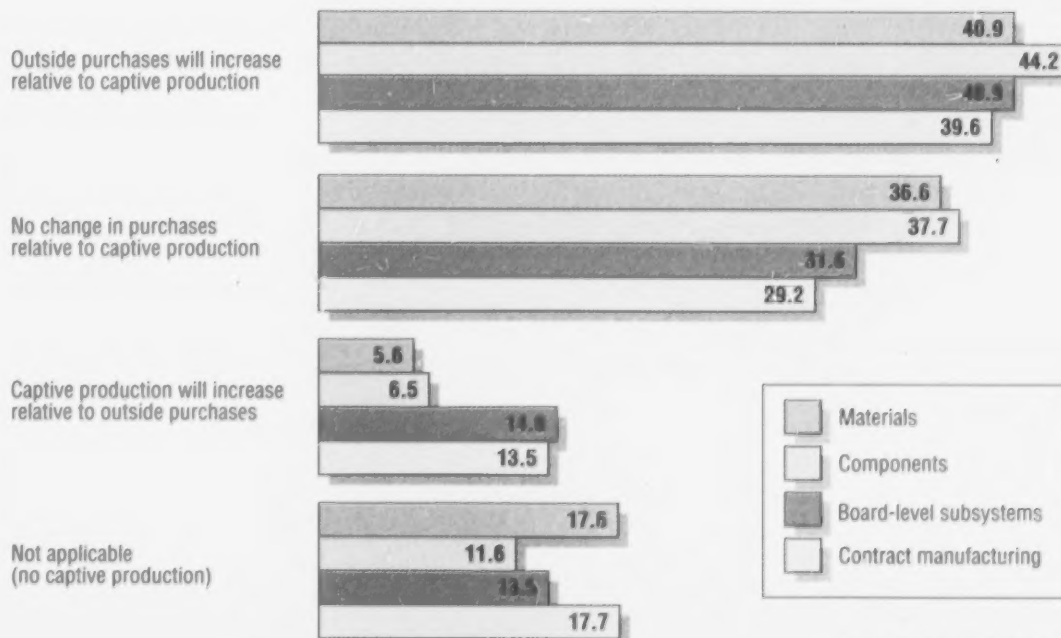
How does your partnering measure up?

Vendors' responses to the following are based on the hypothetical assumption that they have partnered with a supplier and are in the commercialization/production phase

	Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree
Prior to commercialization, vendor agrees to pay all development expenses and capital costs incurred by the materials partner					
Materials partner agrees to pay development expenses and capital costs prior to production					
Vendor's materials partner has sole source position for life of program assuming original design/cost targets are satisfied					
Vendor's materials partner has a sole source position for first year of program, after which other suppliers would be given consideration					
A 10-15% lower price offer from a second source forces qualification of other source and splitting of business between two suppliers					
Vendor's materials partner openly sells material developed jointly after product is commercialized					
Vendor's materials partner is precluded from selling material developed jointly for one year after product is commercialized					

How will your dependence on outside suppliers change?

(Suppliers use over next 3 years; % respondents)



Source: ELECTRONIC BUSINESS and DuPont

PRODUCT DEVELOPMENT & MANUFACTURING

CEO's say product development is vital

(% ranking important factors critical to their competitiveness)

		Ranking		
		1991*	1992	1996**
Product quality	67%	3	1	1
Customer service	65	4	2	2
New product development	52	NA	3	3
Technology innovation	50	1	4	4
Attract and retain key people	45	2	5	6
Time to market	42	7	6	5
Capital availability	32	5	7	10
Organized excellence	32	6	8	7
Proprietary intellectual property	24	8	9	8
Access to foreign markets	22	9	10	8
Supplier realationships	20	10	11	11
Strategic alliances	15	NA	12	12

Multiple responses allowed.

NA=Not available

*Ranking from 1991 CEO survey

**CEO's anticipated ranking

Source: ELECTRONIC BUSINESS and DuPont

What kind of partner are you?

How would you share costs and benefits with a supplier on a successful joint venture
(% respondents)

	Agree	Neither agree or disagree	Disagree	Don't know
Prior to commercialization we would pay all development expense and capital costs incurred by our materials partner.	14.0	20.5	46.2	17.3
We would expect materials partner to pay their development expenses and capital costs prior to commercialization.	45.4	23.3	13.6	15.7
Our materials partner would have a sole source position for life of the program assuming original design/cost targets are satisfied.	27.3	19.3	36.2	14.5
Our materials partner would have a sole source position for the first year of the program, after which alternatives would probably be given strong consideration.	37.4	23.7	20.4	14.9
A 10-15 percent lower price offer from a second source would force qualification if other source and splitting of business between two suppliers.	40.1	24.1	16.8	16.4
Our materials partner would be able to openly sell materials developed jointly after our new product is commercialized.	20.1	22.1	39.0	16.9
Our materials partner would be precluded from selling materials developed jointly for one year after our product is commercialized.	38.6	23.3	14.8	20.1

Source: ELECTRONIC BUSINESS and DuPont

FINANCE & ECONOMICS



Whos' on the VC list

Companies on the list responded to a mailed survey by ELECTRONIC BUSINESS. Interestingly, a few who responded asked not to be included. If your company was omitted, please send its name and address to ELECTRONIC

BUSINESS so we may include you in next year's survey. You must respond to our mailed survey to be listed. For more information about venture capital companies: call the National Venture Capital Association at (703) 528-4370.

Company/Address	Contact/Phone	5-year outlook*	No. of companies funded		Investment (\$ millions)		Total paid in capital (\$ millions)	Some companies funded
			Electronics	Total	Electronics	Total		
Accel Partners One Palmer Sq. Princeton, NJ 08542	Don Gooding (609) 683-4500	↔	\$42	\$50	105	130	\$220	Santa Cruz Operation, Broad Band Technologies, Unify, Teleos
Advanced Technology Ventures 10 Post Office Sq. #970 Boston, MA 02109	Albert E. Paladino (617) 423-4050	↔	10	18	11	20	60	Actel, Microwave Networks, Transwitch
Advent International 101 Federal St. Boston, MA 02110	Patrick J. Sansonetti (617) 951-9400	=	46	146	90	290	650	Interleaf, SystemSoft
Alpha Partners 2200 Sand Hill Rd. #250 Menlo Park, CA 94025	Brian J. Grossi (415) 854-7024	↔	14	19	46.6	59.2	58.6	Pinnacle Systems, Bell Microproducts, Network Peripherals
Applied Technology One Cranberry Hill Lexington, MA 02173	Gina Rogers (617) 862-8622	↔	13	15	13.6	15	NA	Fluent Machines, Information Storage Devices, Reflection Technology
Aspen Ventures 3000 Sand Hill Rd. #3-105 Menlo Park, CA 94025	David Crockett (415) 854-3300	=	40	80	70	130	150	None supplied
Atlas Venture One Cambridge Center Cambridge, MA 02142	Barry Fidelman (617) 621-1600	↔	NA	NA	100	150	200	Bachman Information Systems, Chipcom, Viewlogic Systems
AVI Management Partners 3000 Sand Hill Rd. #3-280 Menlo Park, CA 94025	Peter L. Wolken (415) 854-0930	↔	32	32	50	50	65	Power Up Software, Echelon, Maspar Computers
BancBoston Ventures 100 Federal St. Boston, MA 02110	Henry W. Newman (617) 434-2442	=	10	44	6	36	NA	WaveTracer, SunDisk, In Focus Systems
Batterson Johnson & Wang 303 W. Madison #1110 Chicago, IL 60606	Leonard A. Batterson (312) 269-0300	=	NA	16	8.4	13	33	Answer Computer, IKOS Systems, Clear Communications
Battery Ventures 200 Portland St. Boston, MA 02114	Richard D. Frisbie (617) 367-1011	=	40	40	55	55	75	Marcam, In Focus Systems, Banyan Systems

* ↗ expect to increase investment, ↘ decrease, = stay the same, NA = not available

FINANCE & ECONOMICS

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VENTURE CAPITOL DIRECTORY

Company/Address	Contact/Phone	5-year outlook*	No. of companies funded		Investment (\$ millions)		Total paid in capital (\$ millions)	Some companies funded
			Electronics	Total	Electronics	Total		
Bessemer Venture Partners 83 Walnut St. Wellesley Hills, MA 02181	William T. Burgin (617) 237-6050	◇	15	70	30	100	100	Parametric Technologies, Network Management
Boston Capital Ventures 45 School St. Boston, MA 02108	James Houlihan (617) 227-6550	=	NA	NA	NA	NA	65	Revelation Technologies
Brantley Venture Partners 20600 Chagrin Blvd. Shaker Heights, OH 44122	Robert P. Pinkas (216) 283-4800	◇	9	18	8.8	18.5	45	RF Microdevices, DeCrane Aircraft Holdings, Inplex
Brentwood Associates 11150 Santa Monica Blvd. #1200 Los Angeles, CA 90025	G. Bradford Jones (310) 477-6611	=	30	60	90	NA	400	Media Vision, Wellfleet Communications, Lucid
Burr, Egan, Deleage & Co. One Post Office Sq., #3800 Boston, MA 02109	Jonathan Flint (617) 482-8020	=	13	116	46	270	450	Powersoft, Broderbund, Cadre
Canaan Partners 105 Rowayton Ave. Rowayton, CT 06853	Jim Fitzpatrick (203) 855-0400	◇	NA	NA	35	100	300	Anadigics, Comstream, Clearpoint Research
Charles River Ventures 67 Batterymarch St. Boston, MA 02110	Michael J. Zak (617) 439-0477	◇	20	30	133	200	250	Cascade Communications, Mainstream Software
Charter Venture Capital 525 University Ave. #1500 Palo Alto, CA 95301	A. Barr Dolan (415) 325-6953	◇	15	30	NA	NA	NA	Metricom, Interfax, ELF Technologies
Chatham Venture 420 Bedford St. Lexington, MA 02173	Euan Malcolmson (617) 863-0970	=	10	10	27	27	25	Banyan Systems, Videotelecom, Wall Data
Concord Partners 535 Madison Ave. New York, NY 10022	John Foster (212) 906-7100	=	18	45	50	150	130	SunDisk, Dayna Communications, Read-Rite
Continental Illinois Venture 231 LaSalle St. Chicago, IL 60697	Marcus Wedner (312) 828-8021	◇	3	20	NA	100	NA	None Supplied
Cornerstone Ventures 2420 Sand Hill Rd. #202 Menlo Park, CA 94025	J. Michael Gullard (415) 854-2576	=	20	20	13	13	21	Photonics, Southwest Network Services, Rasna
Crosspoint Venture Partners One First St. Los Altos, CA 94022	John Mumford (415) 948-8300	◇	30	50	60	100	120	STAC, Photonics, Adaptive Solutions
Dajon Consulting 9 Lundy Ln. Larchmont, NY 10538	Robert Cohen (201) 947-4945	=	1	2	NA	NA	NA	None Supplied
Dougery, Jones & Howard 155 Bovet Rd. #650 San Mateo, CA 94402	John R. Dougery (415) 358-8701	◇	45	50	90	100	130	In Focus Systems, Intevac, Abtox
Drysdale Enterprises 859 Promontory Dr. West Newport Beach, CA 92660	George Drysdale (714) 675-5577	◇	4	8	NA	NA	20	None Supplied
E.M. Warburg, Pincus & Co. 466 Lexington Ave. New York, NY 10017	William H. Janeway (212) 878-0600	◇	20	85	250	2,100	2,100	None Supplied

* ◇ expect to increase investment, ◆ decrease, = stay the same, NA = not available

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Company/Address	Contact/Phone	5-year outlook*	No. of companies funded		Investment (\$ millions)		Total paid in capital (\$ millions)	Some companies funded
			Electronics	Total	Electronics	Total		
Eastech Management 260 Franklin St. #530 Boston, MA 02110	Michael H. Shanahan (617) 439-6130	=	16	18	28	30	34	Unifi Communications, Banyan Systems, Pilot Software
EG&G Ventures 700 E. El Camino Real #270 Mountain View, CA 94040	Andres A. Buser (415) 967-2822	=	8	19	14	33	48	None Supplied
El Dorado Ventures 2 North Lake Ave. #550 Pasadena, CA 91101	Brent Rider (818) 793-1936	◊	20	21	58	60	95	Novellus Systems, Cellular Data, Voice Soft
Euclid Partners 50 Rockefeller Plaza New York, NY 10020	Milton J. Pappas (212) 489-1770	◊	9	15	NA	NA	50	Crosscom, Banyan Systems, Itron
Fidelity Capital 82 Devonshire St. #R25C Boston, MA 02109	Neal Yanofsky (617) 728-6846	◊	5	19	14	110	160	Acticom, Imaging Technology, Advanced Mobilcomm
First Century Partners 1345 Avenue of the Americas New York, NY 10105	Michael J. Myers (212) 698-6383	◊	18	43	48	110	130	Evernet Systems, SuperMac Technology, Automation Partners
Fostin Capital P.O. Box 67 Pittsburgh, PA 15230	Joel P. Adams (412) 928-1409	=	14	50	85	17	85	Southwest Network Services, Metcal, Suprex
Geocapital Partners 2115 Linwood Ave. Fort Lee, NJ 07024	Richard Vines (201) 461-9292	◊	24	24	35	35	45	Catalina Marketing, Fifth Generation Systems
Glenwood Management 3000 Sand Hill Rd., #4-230 Menlo Park, CA 94025	Dag Tellefsen (415) 854-8070	=	15	20	30	43	70	Paradigm, Magellan, Biological Components
Glynn Capital Management 3000 Sand Hill Rd., #4-235 Menlo Park, CA 94025	John W. Glynn (415) 854-2215	◊	19	26	16	22	25	Banyan Systems, Ultranetwork Technologies, Celeritek
Grace Horn Ventures 20300 Stevens Creek Blvd., #330 Cupertino, CA 95014	Mark Dubovoy (409) 725-0774	◊	NA	NA	38	60	82	Ministor Peripherals, ELF Technologies
Greylock Management One Federal St. Boston, MA 02110	William H. Helman (617) 423-5525	◊	42	66	73	132	300	Xircom, Banyan Systems, Checkfree
Hambro International Equity Partners 650 Madison Ave. New York, NY 10022	Julie Lane (212) 223-7400	=	45	73	69.5	139.2	150	Avatar Technologies, IDE, Rasna
Highland Capital Partners One International Pl. Boston, MA 02110	Paul A. Maeder (617) 330-8765	◊	6	17	18	50	150	Sybase, Avid Technology, Checkfree
Hill, Carman, Kirby & Washing 885 Arapahoe Ave. Boulder, CO 80302	John G. Hill (303) 442-5151	=	4	48	5	70	118	Crystal Semiconductor, Seattle Silicon
HMS Capital Partners 170 Middlefield Rd. #150 Menlo Park, CA 94025	R.G. Grey (415) 324-4672	=	13	16	11	13	19	Multipoint Networks, Meridian Data Systems
Hook Partners 3102 Oak Lawn Ave. The Centrum #545 Dallas, TX 75219	David J. Hook (214) 528-5451	=	24	25	20	21	25	Vitesse Semiconductor, Slate, Triquint Semiconductor

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Company/Address	Contact/Phone	5-year outlook*	No. of companies funded		Investment (\$ millions)		Total paid in capital (\$ millions)	Some companies funded
			Electronics	Total	Electronics	Total		
IAI Venture Capital Group 3800 First Bank Pl., Box 357 Minneapolis, MN 55440	Thomas G. Kamp (612) 376-2835	=	10	30	30	123	160	Tricord Systems, Racotek, Computer Aided Service
Idanta Partners 10975 Torreyana Rd. #304 San Diego, CA 92122	Dev Purkayastha (619) 452-9690	↔	5	5	11	11	100	Iomega, Stac Electronics, Pacific Communication Sciences
Indosuez Ventures 3000 Sand Hill Rd. #2-160 Menlo Park, CA 94025	David E. Gold (415) 854-0587	=	20	25	NA	NA	34	Informix, Digital Research, Cisco Systems
Inman & Bowman Four Orinda Way, #D150 Orinda, CA 94563	Grant M. Inman (510) 253-1611	↔	14	21	20	32	43.5	Network Computing Devices, Viewstar, Unify
InterWest Partners 3000 Sand Hill Rd. #3-255 Menlo Park, CA 94025	Therese J. Kollerer (415) 854-8585	=	23	54	98	203	250	Cyrix, Radius, Stratacom
J.H. Whitney & Co. 630 Fifth Ave. #3200 New York, NY 10111	Michael Brooks (212) 757-0500	↔	20	50	50	120	400	Vitesse Semiconductor, Wellfleet Communications
JAFCO America Ventures 180 Maiden Ln., 21st fl. New York, NY 10038	Shoichi Fujikawa (212) 269-8900	↔	13	23	15	25	NA	Gensym, Microwave Module ar Devices, Netrix Systems
Kleiner Perkins Caufield & Byers 2200 Geng Rd., #205 Palo Alto, CA 94303	Floyd Kvamme (415) 424-1660	↔	100	150	350	450	500	GO, EO, Power Integrations
Lawrence, Tyrrell, Ortale & Smith 515 Madison Ave., 29th floor New York, NY 10022	Brian Horey (212) 826-9080	=	8	22	27	80	115	Centerline Software, On Technology, Tazarian
Marathon Venture Partners 388 Market St. #900 San Francisco, CA 94111	Thomas J. Bonomo (415) 989-1915	=	7	9	14	17	50	PEER Networks, IRIS Medical, Crosspoint Systems
Mass. Technology Development 131 State St. #215 Boston, MA 02109	Robert J. Crowley (617) 723-4920	=	25	31	7	8.5	13	Kronos, MicroTouch Systems, Voicetek
Mayfield Fund 2200 Sand Hill Rd. Menlo Park, CA 94025	Glenn M. Mueller (415) 854-5560	=	51	73	NA	370	NA	Aspect Telecommunications, MIPS Computer, Silicon Graphics
MDT Advisers 20 Acorn Park Cambridge, MA 02140	Schorr Berman (617) 864-5770	=	6	17	NA	40	NA	Anadigics, Wave Tracer, Cobotyx
Menlo Ventures 3000 Sand Hill Rd., #4-100 Menlo Park, CA 94025	DuBose Montgomery (415) 854-8540	↔	100	120	110	135	285	Frame Technology, Retix, Xyplex
Merrill, Pickard, Anderson & Eyre 2480 Sand Hill Rd. #200 Menlo Park, CA 94025	Steven L. Merrill (415) 854-8600	↔	54	61	96	103	285	Network Computing Devices, Synopsis, PictureTel
MK Global 2471 E. Bayshore Rd., #520 Palo Alto, CA 94303	Greg Lahann (415) 424-0151	=	17	22	53	60	65	Document Technologies, Netframe Systems, Proxim
Mohr, Davidow Ventures 3000 Sand Hill Rd. #1-240 Menlo Park, CA 94025	Lawrence G. Mohr (415) 854-7236	↔	29	34	34	41	71	Actel, Auspex Systems, Rambus

* ↗ expect to increase investment, ↘ decrease, = stay the same, NA = not available

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Montgomery Bridge Funds 600 Montgomery St. #2100. San Francisco, CA 94111	John C. Siegler (415) 627-2039	=	25	40	68	95	100	MicroLinear, Metricom, Resound
Morgan, Holland Ventures One Liberty Sq. Boston, MA 02109	Ed Kania (617) 423-1765	◊	20	30	40	65	100	Star Semiconductor, Dataware Technologies, Microwave Logic
Morgan Stanley & Co. 1251 Avenue of the Americas New York, NY 10020	Guy de Chazal (212) 703-4000	=	40	50	60	80	100	Ross Systems, Bachman Information, Sanmina
Morgenthaler Ventures 629 Euclid Ave. Cleveland, OH 44114	Theodore A. Laufik (216) 621-3070	=	14	42	32	75.8	160	Microchip Semiconductor, Vitesse Semiconductor, Synopsys
Wazem & Co. 600 Madison Ave., 14th fl. New York, NY 10022	Fred F. Nazem (212) 644-6433	◊	21	36	90	150	150	Mediavision, Spatial Technology, Momena
New Enterprise Associates 1119 St. Paul St. Baltimore, MD 21202	Nancy Dorman (301) 244-0115	◊	108	169	163	254	394.2	Syquest Technology, Vitesse Semiconductor
Newtek Ventures 500 Washington St. #720 San Francisco, CA 94111	John E. Hall (415) 986-5711	◊	NA	NA	18	23	54	Logic Modeling, Spectralink, Caere
Norwest Venture Capital Management 222 S. Ninth St. Minneapolis, MN 55402	Promod Hague (612) 667-1650	◊	NA	NA	48	156	NA	Actel, Performance Semiconductor, Peoplesoft
Oak Investment Partners 3000 Sand Hill Rd. #3-240 Menlo Park, CA 94025	David P. Best (415) 854-8825	◊	37	69	269	324	495	Synopsys, Picturitel, Wellfleet Communications
Olympic Venture Partners 2420 Carillon Point Kirkland, WA 98033	George H. Clute (206) 889-9192	◊	16	22	NA	NA	70	Logic Automation, Triconex, Verity
Oxford Partners 1266 Main St. Stamford, CT 06902	William R. Lonergan (203) 964-0592	=	27	47	50	105	122	Vitesse Semiconductor, Zitel, Video/Phone
Paragon Venture Partners 3000 Sand Hill Rd. #2-190 Menlo Park, CA 94025	Robert F. Kibble (415) 854-8000	◊	12	26	32	42	70	Pages Software, Bimillennium, Topomex
Partech International 101 California St. #3150 San Francisco, CA 94111	Vincent Worms (415) 788-2929	=	3	7	3	8	200	Ascend Communications, Biosym Technologies
Pathfinder Venture Capital Funds 7300 Metro Blvd. #585 Minneapolis, MN 55435	Brian P. Johnson (612) 835-1121	◊	26	57	30	65	100	Digital Systems Intl., Confertech Intl., Optical Specialties
Poly Ventures Polytechnic University, Rt. 110 Farmingdale, NY 11735	Shelley A. Harrison (516) 249-4710	◊	5	15	NA	NA	53	None Supplied
Sequoia Capital 300 Sand Hill Rd. #4-280 Menlo Park, CA 94025	Donald T. Valentine (415) 854-3927	◊	120	200	NA	400	NA	Cisco Systems, Central Point Software, Auspex
Sevin Rosen Fund Two Galleria Tower #1670 13455 Noel Rd. Dallas, TX 75240	Jon Bayless (214) 702-1100	=	32	35	110	120	200	Videotelecom, Cyrix Semiconductor, Cyberonics

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Shaw Venture Partners 111 Southwest Fifth Ave. #2200 Portland, OR 97204	Alan S. Dishlip (503) 228-4884	◇	20	29	24	30	50	Protocol Systems, Aptix, Voxel
Sierra Ventures 3000 Sand Hill Rd. #4-210 Menlo Park, CA 94025	Vincent H. Tobkin (415) 854-1000	◇	40	60	NA	NA	160	Stratacom, Epoch Systems, Intuit
Sigma Partners 2884 Sand Hill Rd. #215 Menlo Park, CA 94025	Lawrence G. Finch (415) 854-1300	◇	42	44	65	70	120	Supermac Technology, Stac, Wellfleet Communications
Spectra Enterprises Associates 200 N. Westlake Blvd. #215 Westlake Village, CA 91362	James A. Cole (805) 373-8537	=	NA	17	NA	NA	NA	None Supplied
St. Paul Venture Capital 385 Washington St. St. Paul, MN 55102	Fredric R. Boswell (612) 223-2135	◇	20	50	100	300	NA	Tricord Systems, Broad Band Technologies, Cayman Systems
Summit Partners One Boston Place Boston, MA 02108	Karen Young (617) 742-5500	◇	26	56	42.2	68.6	675	Boca Research, Artisoft, McAfee Assoc.
Sutter Hill Ventures 755 Page Hill Rd. #A-200 Palo Alto, CA 94304	Paul M. Wythes (415) 493-5600	◇	10	45	NA	NA	NA	Edify, Forte, Aspect
TA Associates 45 Milk St. Boston, MA 02109	Stephen J. Gaal (617) 574-6700	=	46	70	250	325	500	Epoch Systems, BroadBand Technologies, Trident Microsystems
Technology Funding 2000 Alameda de las Pulgas San Mateo, CA 94403	David Titus (415) 345-2200	◇	15	30	100	200	260	Geoworks, Primary Access, Reflection Technology
Technology Venture Investors 2480 Sand Hill Rd., #101 Menlo Park, CA 94025	Mark G. Wilson (415) 854-7472	◇	NA	40	150	172	270	Synopsys, Farallon Computing, Intuit
Trinity Ventures 155 Bovet Rd. #660 San Mateo, CA 94402	Noel J. Fenton (415) 358-9700	=	20	36	27	49	76	Alldate, Answer, Wall Data
TVM Techno Venture Management 45 Milk St. Boston, MA 02109	Waldemar Jantz (617) 457-5251	◇	25	65	50	120	220	Digital Research, Netrix Systems, Keyfile
Vanguard Associates 525 University Ave. #600 Palo Alto, CA 94301	Jack M. Gill (415) 321-2900	◇	29	48	26	51	63	Tricord Systems, Topometrix, Databeam
Vencon Management 301 W. 53rd St. New York, NY 10019	Alina Fisch (212) 581-8787	◇	NA	NA	NA	NA	NA	None Supplied
Venrock Associates 30 Rockefeller Plaza #5508 New York, NY 10112	Peter O. Crisp (212) 649-5657	◇	30	50	NA	NA	NA	Echelon, Photon Dynamics, Photonics
Venture Capital Fund of New England 160 Federal St., 23rd fl. Boston, MA 02110	Kevin J. Dougherty (617) 439-4646	◇	17	31	13	24	48	Progress Software, New Media Graphics, Intra-Sonix
Venture First Associates 1400 Lake Hearn Dr. #205 Atlanta, GA 30319	J. Douglass Mullins (404) 843-5545	◇	5	30	NA	NA	NA	None Supplied

* ◇ expect to increase investment, ● decrease, = stay the same; NA = not available

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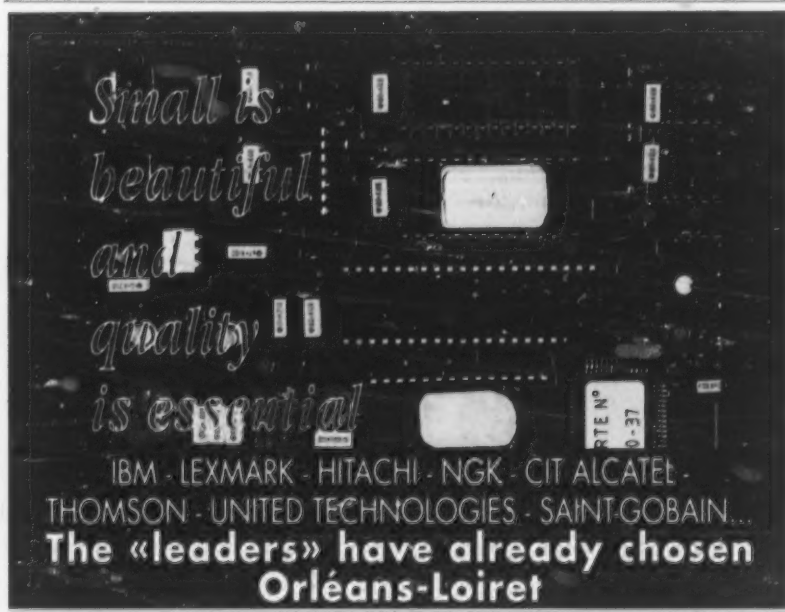
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Venture Funding Group international 49 West 12th St., Executive Suite New York, NY 10011	Allan E. Skora (212) 691-9895	◇	10	12	NA	NA	NA	None Supplied
Walden Group 750 Battery St., 7th fl. San Francisco, CA 94111	Arthur S. Berliner (415) 391-7225	◇	33	50	25	100	150	Creative Technologies, RasterOps, S3
Weiss, Peck & Greer Venture Partners 555 California St., #4760 San Francisco, CA 94104	Philip Greer (415) 622-6864	=	22	50	49	133	225	Network Computing Devices, MicroLinear, Harmonic Lightwaves
Wind Point Partners 1525 Howe St. Racine, WI 53403	James Forrest (414) 631-4553	◇	8	50	18	104	126	Effective Management Systems, Climcom, CAD Information Systems
Woodside Fund 850 Woodside Dr. Woodside, CA 94062	Vincent M. Occhipinti (415) 368-5545	◇	12	16	11	15	30	None Supplied
Xerox Technology Ventures 101 Continental Blvd. #ESC1-110 El Segundo, CA 90245	Robert V. Adams (301) 333-2639	◇	6	11	15	30	25	Advanced Encryption Systems, Quiyote Products, Terabank Systems
Zero Stage Capital 101 Main Street Cambridge, MA 02142	Gordon B. Baty (617) 876-5355	◇	15	35	16	30	40	Swan Technologies, Mercury Computer Systems, Octocom Systems

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ILLUSTRATION BY MICHAEL K. HARRIS

U.S. equipment vendors leverage IC know-how into LCDs

Sharp, Toshiba, and other companies seek help in improving their display yields, but some analysts warn against a "phantom market"

By Barbara Jorgensen

A handful of U.S. semiconductor equipment vendors may be the best bet for overcoming the yield problems plaguing makers of thin-film transistor (TFT) liquid crystal displays (LCDs), a market that is dominated by Japan. Some, including Applied Materials Inc., KLA Instruments Corp., and GenRad Inc. are developing LCD equipment at their Japanese customers' request—a move that augurs well for the U.S. equipment industry.

"That Japan is going to outside vendors indicates that their internal support structure cannot solve these problems," says Scott Young, technology director at Semiconductor Equipment and Materials International (SEMI), an equipment trade group. "They've learned the limitations of their [domestic] suppliers."

Companies such as Dainippon Screen, Nippon Mining Co., and Toshiba are even investing in Yankee ingenuity in hopes of improving their manufacture, test, and repair of TFT active-matrix (AM) displays. Japan is the only volume manufacturer of the displays, which require much of the same production technology as ICs (see chart).

Whether that's a long-term opportunity for U.S. vendors, however, is open to question. The low yields and economic slump in Japan have stalled the active-matrix display market—which Nomura Research Institute once predicted would reach \$7.5 billion by 1995 but now pegs at \$3.7 billion—and that has many industry

analysts and vendors wondering when, if ever, the market will reach fruition. "We're surprised at how slowly these [yield] problems have been solved," says William Schneider, vice president of marketing and sales at MRS Technology Inc. in Chelmsford, Mass., which sold its first LCD-customized lithography machine in 1988. "The reason may be that we thought everyone could develop innovative technology quickly. But Japan does not have a tradition of quickly turning around innovative solutions."

Yields of usable TFT displays in Japan are now thought to run only 30% to 50%, resulting in displays priced between \$1,200 and \$1,500. The panel's size makes manufacturing-related lines, gaps, and dots

highly visible on a lighted screen; a bad connection or short circuit renders a costly display useless. Current test methods determine that the panel works or doesn't. Japanese LCD manufacturers—the top tier includes Sharp, Toshiba, NEC, and Hitachi—are predictably closed-mouthed about their manufacturing limitations, but a recent report notes that one manufacturer's panels are beset by short circuits 38% of the time; by short circuits between layers 27% of the time; and by open circuits 13% of the time. Most failures are due to particles adhering to the devices.

For some U.S. equipment makers, a market stalled by manufacturing problems spells new business. "Many emerging markets exhibit the

behavior that the LCD market has," says Bob Boehlke, CFO of KLA Instruments in San Jose. "There's a quick round of enthusiasm, then a retrenchment as yields are worked out, and then finally a rebound and growth period."

Still, once production problems are solved, one analyst thinks the new-equipment market will dry up. "It's a phantom market," Dan Hutcheson, president of VLSI Research Inc. in San Jose, says flatly. Drivers of the LCD equipment market, he explains, are not the invisible submicron line-

Similarities in IC and TFT AMLCD production . . .

- Use of photolithography
- Intensive use of thin-film processing
- Requirement of large capital investment
- Use of fundamentally low-cost materials
- Process-intensive
- Manufacturing costs are highly yield dependent

. . . and how they differ

- TFT LCDs are made with one "chip" per wafer
- TFTs use much larger geometries
- TFT LCD substrate costs increase linearly with area
- TFTs require fewer mask steps
- TFTs have a smaller base of art and science
- TFTs afford no benefit of higher yield for smaller die dimensions
- Epitaxial layers are not possible

Source: Stanford Resources Inc.

MARKETS

widths and high integration of the IC market, but what is perceived by the human eye. Once gaps, shorts, and dots are eliminated, he explains, capital spending will be diverted to volume manufacturing equipment. Even a manager with Tokyo Electron Ltd. (TEL), which co-developed and sells an LCD test system with GenRad and distributes for Micron Corp., agrees. "The market is probably one-tenth the size of the IC equipment market, and it won't grow like that market did. People will keep using the same equipment for a long time," says Kenji Washino, section chief of TEL's LCD group.

Others are advising caution at the very least. San Francisco-based Hambrecht & Quist's Carolyn Rogers says TFT LCDs are best approached as an extension to already established business, as with Applied Materials, which is spinning off a wholly owned subsidiary, Applied Display Technology (ADT), in Japan. "It's a good market to look at strategically, but flat panels aren't semiconductors," says Rogers. "In semis, materials aren't a big deal—but in panels, a lot of the cost is in materials." Rogers estimates the 1995 AMLCD equipment market could reach \$700 million (see sidebar).

U.S. companies that are successfully penetrating the market are doing so through partnering or by bringing something new to the party. Santa Clara, Calif.-based Applied Materials, the recognized leader in clean chemical vapor deposition (CVD), is co-developing CVD equipment with LCD manufacturer Toshiba. Both San Jose-based Photon Dynamics Inc. and Peabody, Mass.-based Micron have developed innovative repair systems.

Toshiba and Applied Materials will co-develop production systems in CVD, plasma etching, and physical vapor deposition that improve the process at the production end. The fact that Applied Materials has entered the TFT market confirms for some that the market clearly exists. Market watchers are quick to note, however, that LCDs will probably comprise only a small part of Applied Materials' overall business. "Applied

Top LCD manufacturers

Sharp
Hitachi
Toshiba
Sanyo
Matsushita
Hosiden
NEC

Source: Hambrecht & Quist

had its reasons [for teaming up with Toshiba] beyond market size," says Hutcheson. "It's part of its overall strategy—even Applied is not that convinced it will be a big market."

"The LCD business is complemen-

Once gaps, shorts, and dots are eliminated, capital spending will be diverted to volume manufacturing equipment

tary to our core business," counters Norm Turner, managing director of ADT, "and those techniques are being employed in this new product development." Turner will not comment on whether its arrangement with Toshiba includes investment money: ADT expects to have initial CVD product on the market by the end of 1992. "We are well positioned to make the transition from IC equipment to TFT," adds Turner. "Japanese companies will

go wherever they think they'll get a competitive advantage."

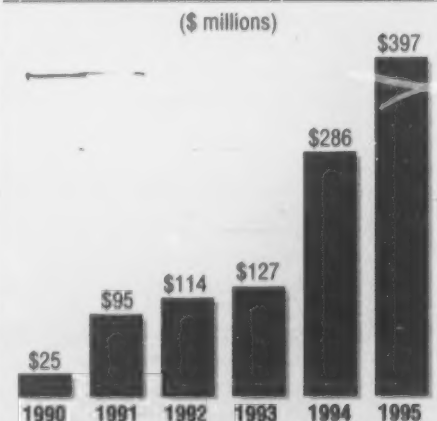
Also vying for the front-end is MRS Technology, with possibly the largest installed base—"in the teens," allows Schneider—of any U.S. vendor of LCD equipment. Getting to market first so far has been a big advantage—Tokyo-based market research firm Global Net gives MRS Technology top share through '91 in LCD lithography. However, Canon and Nikon are catching up fast now that the market is, in theory, ramping up toward mass production, adds Global Net's director, Yasuhiko Takeno.

Although domestically there are no AMLCD fabs in volume production, MRS Technology has three lithography machines installed in the United States. One is at the David Sarnoff Laboratories in Princeton, N.J. Sarnoff has a "mini-fab" used for prototype development and R&D aimed at bringing AMLCD production on-shore. MRS's equipment is used to produce 14-inch AMLCDs—much larger than the 10-inch screens giving Japanese manufacturers trouble—says Arthur Firester, head of display applied research and development at Sarnoff. "This was the best machine for our purposes," he says, citing the equipment's scalability and flexibility of adapting to larger-size screens.

Firester points out that the equipment is not being used for mass production but adds, if it were, "we'd expect the reliability would be high and the costs low."

For in-process test, KLA Instruments and Nippon Mining formed a joint venture, KLA Acrotec, to manufacture inspection equipment. KLA Acrotec's 6000 inspection system does in-process digital-image processing of panels and can identify where in the process defects occur, allowing repair before final assembly. In such a partnership, Boehlke stresses the necessity of being close to the customer, particularly in a developing mar-

TFT LCD stepper market



Source: Stanford Resources

MARKETS

ket. "Our customers are in Japan, so that's where we formed a joint venture," he says. "You have to be next to your customers and be ready to respond to their problems. [In inspection], we have a leading technology and our IC customers nearby, so we've been able to customize the product."

The next best thing to flawless lithography and deposition is in-process test and repair. Along with KLA, Photon Dynamics, Micrion, and GenRad have offerings in those areas. Only Photon Dynamics and Micrion, however, offer actual repair alternatives. Both companies have installed bases of six systems.

Nine-year-old Micrion, a manufacturer of ion-beam IC equipment for photomask repair and wafer process monitoring, began looking into leveraging that ability into LCD repair four years ago. The L1 Series uses a laser beam for both metal removal and low-temperature deposition to repair TFT displays. Micrion's L1 program manager, Richard Comunale, sees LCDs as a natural expansion of Micrion's technology and customer base. "We've been dealing with Japan for a while," he says, "and if you don't do well there, you don't do well." Micrion does not have a major Japanese development partner or financial backer, but it does sell equipment through TEL. KLA

is also an investor in Micrion.

Fast-rising Photon Dynamics has perhaps the only full-system solution for LCD inspection, test, and repair. Along with its voltage-imaging test system, Photon Dynamic's repair system uses a laser to deposit films or write metal lines on the LCD. President Francois Henley counts himself among the LCD market optimists, although all of Photon Dynamics' equipment can be used for other flat-panel displays. Photon Dynam-

Even pessimists agree that the long-term potential for TFT displays is huge

ics will be soon be expanding its product line to assembled panel inspection. "Panels have variations," says Henley, "in color and in hue. We can even establish grades of panels."

The GenRad/TEL GTS-1 test-and-measurement system is capable of automated in-process substrate test and diagnosis through GenRad-developed software. Although customer feedback from Japan is notoriously sketchy and often confidential,

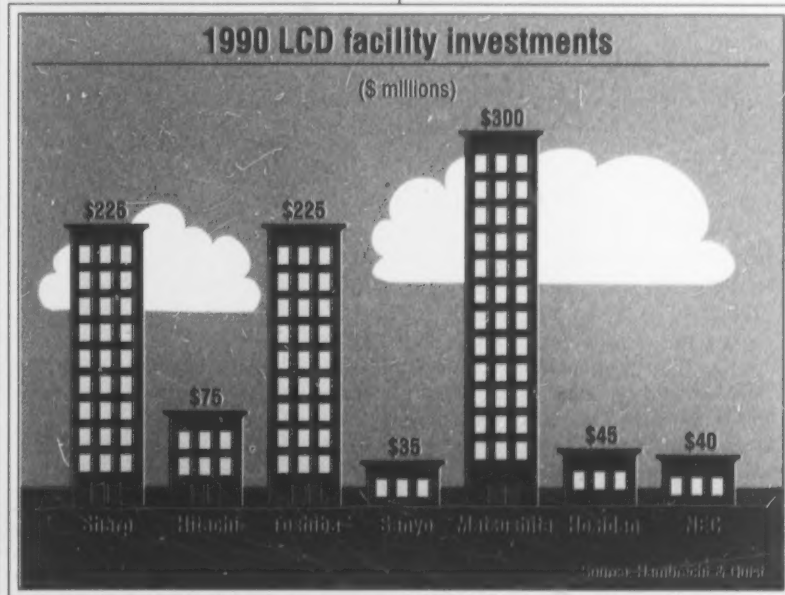
TEL's Washino reports that eight of the largest Japanese LCD makers have expressed an interest in GenRad's tester. Still, he cautions, "There is a high probability that customers [in Japan] will choose the company that offers better service." Not coincidentally, this is what TEL does for U.S. companies. "They can't afford to have that whole expensive line down, and they most likely have no budget for repairs," Washino adds. "So you have to fix it for free and as soon as possible."

"In a way, selling in Japan is easier because, once you establish the relationship, it doesn't matter so much if your machine's performance or price is a little worse," adds Washino. Maybe. There's still another aspect of selling in Japan that U.S. equipment makers are highly aware of, but have no fast solution. As Applied's Turner notes: "Nothing guarantees against reverse engineering."

MRS's Schneider says the only sure way creates another dilemma. "The only way to stop [eventual Japanese encroachment] is to stay one step ahead," he says. "But how do you fund that? It's a structural problem, especially in the United States. It cost us \$18 million to get the first machine developed."

WILL JAPANESE VENDORS eventually replace the early U.S. innovators? "It depends on how well the U.S. responds and how well [vendors] control their intellectual property interest," says SEMI's Young. "I don't think it will follow the standard paradigm—the industry now is more capable of dealing with these issues" than it was in the 1980s.

"The other part of the equation," adds Young, "is whether the U.S. will develop and build display devices that will fuel local demand for equipment. That's an overall competitive issue—the U.S. has no indigenous display capability," which forces U.S. computer makers to source from many of their competitors. Optical Imaging Systems in Troy, Mich., makes AMLCDs for military consumption, and Xerox PARC in Palo Alto reportedly is researching AMLCD production.



Coming in July:

- Defense Electronics Report
- Customer Satisfaction Report

BUSINESS STRATEGY

- Defense Shakeout
- Defense Debate
- Customer Satisfaction

PRODUCT DEVELOPMENT & MANUFACTURING

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- What's Hidden in DOD's Labs
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MARKETS

- Passive Components
- Digital Signal Processing (DSP)

DIRECTORIES

- International Plant Site Directory

Electronic Business
JULY 1992

Electronic Business

For the Management Team in Electronics, Computer, and Systems Companies

MARKETS

Taking apart the numbers

ONE REASON ANALYSTS have difficulty projecting the AMLCD equipment market is that the LCD markets themselves have not developed the way even the Japanese anticipated. The yield problems have proved daunting, and the recession in Japan has slowed end-product sales and stalled capital investment.

Furthermore, the Japanese are closed-mouthed on their manufacturing problems, processes, and fabs. So, because of high pricing and problems with yields, even the panels' end-market values range from Nomura's optimistic \$3.7 billion market (down from \$7 billion) by 1996, to Stanford Resources' TFT LCD projection of \$1.4 billion by that year.

"I'm not convinced that cost will come down so quickly," says Stanford analyst Dave Mentley. "A whole array of manufacturing issues will first need to be resolved in order to hit these forecasts."

Nomura's equipment market forecast is by far the rosiest, and \$1.5 billion (based on a \$7 billion LCD market) most likely includes all AMLCD equipment, not just TFT. (AMLCDs can also be made by metal-insulated-metal and triple

diode methods). Hambrecht & Quist uses the semiconductor industry model for its projections: Sales of capital equipment used by semiconductor manufacturers account for perhaps 10% of the sales of the devices themselves. So, basing estimates on a \$7 billion AMLCD end-market from a number of published sources, Hambrecht & Quist arrives at a \$700 million equipment market.

Two analysts use a typical AMLCD fab to model their projections. O'Mara and Associates in Palo Alto estimates an overall fab investment at \$145 million to \$150 million, including land and buildings, based on the glass substrate requirement of LCDs, analogous to silicon wafer starts in the IC industry. Stanford Resources, which specializes in the display market, uses a fab model projecting a total capital equipment investment for TFT LCDs at just over \$110 million. Segments include photolithography, \$42 million; deposition/etch, \$45 million; inspection, \$11 million; and the rest of the facility, \$17 million. The model assumes panels are 8 by 10 inches, with more than 450,000 starts of TFT plates per year, at 50% yields. □

The market for active-matrix LCDs hasn't taken off the way the Japanese expected

Even pessimists agree that the long-term potential for TFT displays is huge. Dave Mentley of display research firm Stanford Resources admits that Stanford has one of the most conservative forecasts for TFT LCDs but still anticipates a \$4.5 billion market by 2000. Until manufacturing issues are resolved, however, even Japan's TEL prefers to be conservative regarding the equipment forecast.

"The LCD equipment market *does* have real growth potential, but it's not paradise," says Washino. "For

five years," he concludes, "the market is bright. But in 10 years, it's a question mark."

That said, many U.S. production equipment makers are preparing to enter the market. Those makers that are most likely to succeed in the long term are the companies that are attacking problems yet to be solved in the IC production world. Photon Dynamics, for example, is a good candidate to survive.

Paula Doe contributed to this report from Japan

Market snapshot:

Semiconductor manufacturing and inspection equipment

Worldwide calendar year 1991 sales (\$ millions) and leading vendors' market share*

Deposition

(Includes chemical, physical, and epitaxial)

1991 sales: \$1,237.8



15% Applied Materials
10% Varian



Microlithography

Resist processing

1991 sales: \$363.5



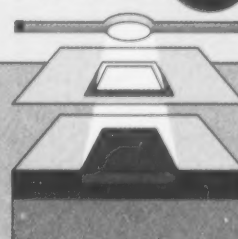
30% Tokyo Electron
25% Dainippon Screen

Steppers (aligners)

1991 sales: \$781.7



55% Nikon
20% Canon

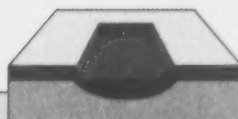


Diffusion Furnaces

1991 sales: \$344.6



35% Tokyo Electron
15% Kokusai



Ion implant

(Includes medium- and high-current)

1991 sales: \$416.9



40% Tokyo Electron
25% Eaton



Dry etch

(Includes strip, etch, and ion mills)

1991 sales: \$1,054.4



25% Applied Materials
15% Tokyo Electron
10% Lam Research

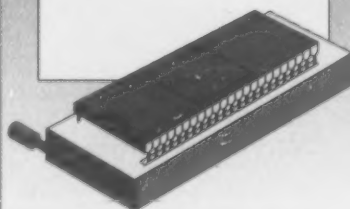


Automatic test

1991 sales: \$1,388.9



20% Advantest
20% Teradyne

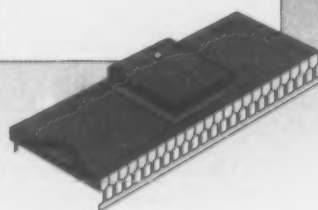


Packaging

1991 sales: \$433.4



15% Towa Electric
15% Yamada
15% ASM

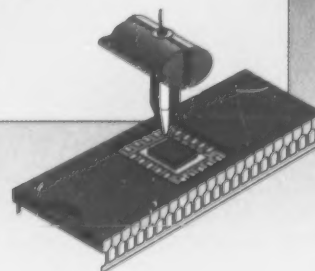


Wire bonders

1991 sales: \$233.0



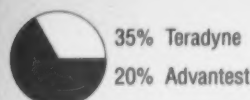
35% Shinkawa
20% Kulicke & Soffa



* This chart shows only the major fabrication, test, and assembly steps. Their markets do not add up to the total worldwide shipments. Market shares are rounded up to the nearest 5%.

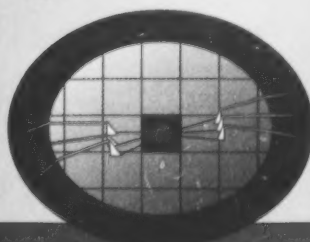
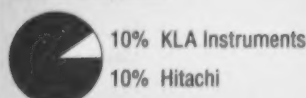
CIM software

1991 sales: \$33.8



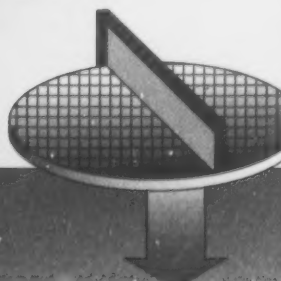
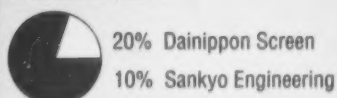
Process diagnostics

1991 sales: \$699.2



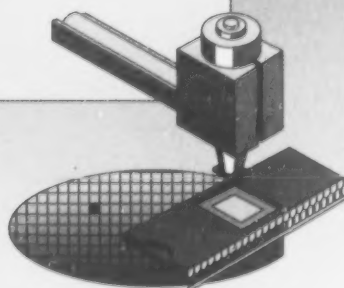
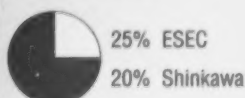
Wafer cleaning systems

1991 sales: \$315.7



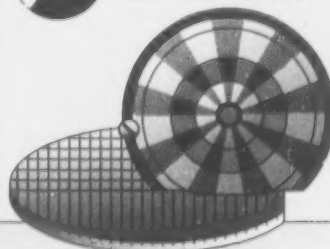
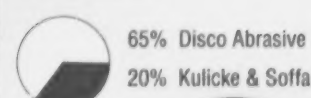
Die bonders

1991 sales: \$85.1



Dicing saws

1991 sales: \$89.8



Source: VLSI Research Inc.

Domestic equipment makers gained market share in '91

Nineteen ninety-one was a good year for U.S. manufacturers of semiconductor production equipment. Applied Materials Inc. rose a notch to replace Nikon as the world's No. 2 equipment supplier (after Tokyo Electron Ltd.), and U.S. companies' share of the global market rose to 40.8%, from 38% in 1990.

"This is a milestone for Sematech, which has been working closely with all of these U.S. companies to improve American manufacturing," says Dan Hutcheson, president of market research firm VLSI Research Inc. He reports that most of the U.S. gain came from Japanese competitors. The top-10 equipment manufacturers retained about 43% of the \$9.9 billion worldwide equipment-and-services market.

The results are key indicators for the semiconductor equipment industry, notes Hutcheson, since they represent a shift away from lithography to chemical vapor deposition—Applied's and TEL's strength—as the dominant technology. Manufacturing issues are shifting from a focus on line-width to film deposition, diffusion, and sputtering.

—By Barbara Jorgensen

The top 10 equipment manufacturers

Company	Estimated sales* (\$ millions)
1. Tokyo Electric	\$764
2. Applied Material	654
3. Nikon	616
4. Advantest	448
5. Canon	360
6. Varian	328
7. Hitachi	316
8. Teradyne	263
9. General Signal	243
10. Silicon Valley Group	235

*1991 rank includes service and spares

Source: VLSI Research Inc.

Low-density MCU market remains robust, though less profitable

The electrification of just about everything keeps demand for 4-bit and 8-bit devices soaring

By Hugh G. Willett

The drive to distribute affordable intelligence in more new places will keep older 4-bit and 8-bit embedded control architectures alive through the end of the decade, according to experts, who point out that low prices and software compatibility are key to keeping the low end of the market growing.

Between 1989 and 1995, dollar sales of low-cost 4-bit and 8-bit devices will continue to grow at compounded annual rates of 1.6% and 13.5%, respectively, according to a study published by Electronic Trend Publications in Saratoga, Calif. At \$5.4 billion, the combined 4-bit and 8-bit markets will still overshadow the \$2.8 billion combined total of the 16-bit and 32-bit markets, the report shows.

"There's no doubt that the high end will offer the biggest growth in terms of average selling prices, but I expect to see positive sales growth in all the market areas for the rest of the decade," asserts Maryann Bader, consultant and author of the ETP report.

Designers are demanding more from existing architectures, driving the introduction of smaller controllers with more features and performance

than many thought possible when the devices were introduced 10 or 15 years ago, Bader claims.

New applications in the automotive, industrial control, consumer, and home appliance markets continue to create opportunities for suppliers of 4-bit and 8-bit MCUs. Storage devices, communications equipment, and entertainment applications can make do quite well with 4-bit and 8-bit processors and controllers, where low cost is key to market acceptance.

At SMOS in San Jose, sales of 4-bit controllers are getting a boost from telephones that need low-end processing power for features such as caller ID, says Robert Wong, director of standard products. Other applications such as exercise machines will keep unit volume growing on these 4-bit devices for at least the next five years, he says.

"These are low-cost devices, probably no more than \$4 each, but the volume runs into the millions," Wong says. "What we do is leverage our manufacturing relationship with Seiko Epson to keep costs down. We are making a profit on these chips."

Areas in which to add value at the 4-bit and 8-bit level include 3-volt operation



MARKETS

and smaller, lower-cost packages, says Wong. As the chips move to Seiko Epson's 0.8-micron technology, power consumption will shrink, costs will drop even further, and performance will increase, adds Wong.

Unlike the traditional microprocessor markets, which quickly move on the next level of computing performance to make obsolete the earlier generations, there are a lot of good reasons to stick with an established embedded architecture for years, or even decades, says Jim Magill, vice president of business development at Zilog in Campbell, Calif.

SOFTWARE, PERFORMANCE, and system-cost reduction are the three most important factors driving the embedded markets, Magill says. All three factors can be addressed at the 8-bit level without moving up to 16-bit and 32-bit processors, for which new software must be developed and more expensive peripheral components purchased, he says.

On the performance and cost reduction side, 8-bit architectures have been able to advance through the integration of memory management units, clocks, and serial ports on the same chip. Magill points out that on-chip peripherals can increase performance and reduce overall systems costs.

NEC Corp. also has a line of 4-bit controllers that can be configured with on-chip peripherals, including analog-to-digital converters and drivers for fluorescent displays, to save space, lower the cost, and increase performance. The controller chips are considered "semi-intelligent" and can be programmed for a variety of applications, says Marty Stolz, product marketing engineer at NEC.

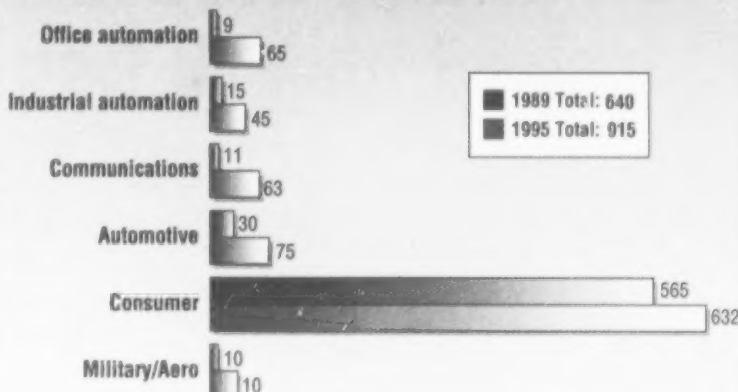
"They find their best use in applications that require a bright vacuum fluorescent display with many digits and segments," he says. "The most common applications are in the consumer electronics and appliance industries."

Another way to increase the performance of 8-bit microcontrollers is

How embedded processor demand is shifting

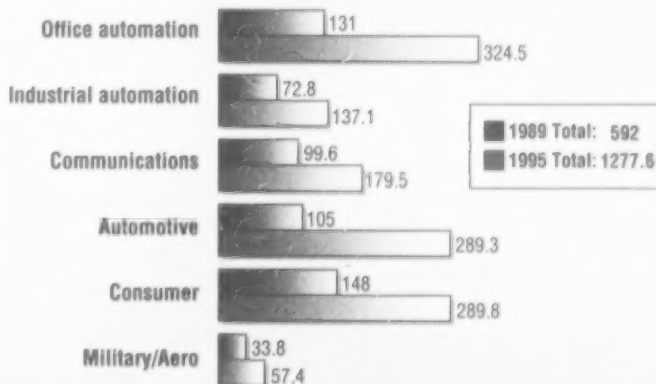
Worldwide consumption (millions of units)

4-bit embedded controllers



8-bit embedded controllers

Worldwide consumption (millions of units)



16-bit embedded controllers

Worldwide consumption (millions of units)



Source: Electronic Trend Publications

Performance drives sales of high-end embedded processors

SALES OF 32-bit embedded processors aren't about to match those of the low-end microcontrollers, but high average selling prices make the market an attractive niche for microprocessor vendors reeling from the confusion and competition in the desktop computer markets.

Battles for the desktop have left some MPU heavyweights searching for homes for their rejected products. Motorola, for example, never quite got its 32-bit RISC-based 88000 off the ground in the desktop market, but it jumped at the chance to position the chip as an embedded processor when Ford Motor Co. expressed interest in the chip for engine control in future generations of automobiles. Whether the Ford "design win" will save the 88000 isn't yet clear, but the episode illustrates how dependent these 32-bit chips can be on a single customer for survival.

Despite the low-cost bias of all embedded processors, performance is still driving many applications, says analyst Maryann Bader. The laser printers' endless appetite for speed is rapidly outstripping the processing ability of more general-purpose 32-bit architectures such as Motorola's 68000, and they now need SPARC and MIPS-based RISC performance, she says.

That need has also created a window for Advanced Micro Devices, National Semiconductor, and In-

tel—all of which have had trouble establishing their RISC offerings as computer engines but have had more success in winning designs as printer and graphics controllers.

Originally targeted at the desktop workstation market, SPARC and MIPS processors have also managed to benefit from the fragmenting market. They can often provide better performance per dollar than high-end microprocessors such as Intel's 486 and Motorola's 68040, says Brian Halla, vice presi-

RISC designs use less silicon, so they're more cost-effective and have room on the silicon for additional features

dent of LSI Logic's Microprocessor Group. RISC designs use less silicon, making them more cost-effective to produce and leaving room on the silicon for additional features, he says.

LSI Logic is offering what Halla jokingly refers to as a "Mr. Potato Head" service, allowing customers to mix and match an assortment of peripherals around the core processor in a manner similar to the way children configure the toy spudman with a variety of appendages. LSI

Logic is using its application-specific IC technology to configure custom logic, memory, and peripheral functions around its SPARC and MIPS-based RISC cores for a powerful single-chip solution to laser printer engines and embedded processing applications such as industrial control.

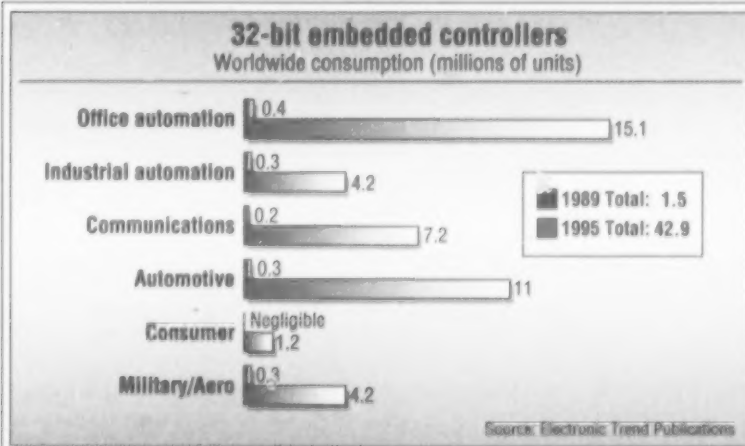
VLSI Technology, using its 32-bit RISC-based ARM core processor, is also offering a cell-based ASIC solution that integrates custom functions around the core processor for embedded solutions. Again, the key to RISC is its efficient utilization of silicon, which gives a powerful solution at the low cost needed for embedded applications.

ANOTHER OPPORTUNITY for U.S. suppliers is the increasing use of digital-signal processing (DSP) for embedded control. Developed for military applications, DSP uses software algorithms in silicon to manipulate digital signals quickly and easily for interface with real-world analog inputs.

"DSP provides more performance for the buck compared with high-cost RISC processors," says Arie Brisch, marketing manager at Motorola. "DSP can perform more functions on a single chip."

Companies such as Motorola and Texas Instruments are applying volume efficiencies to their DSP designs to bring the costs down to the level needed for various applications including those that control large arrays of disk drives. Because DSP provides a lot of software functionality in silicon, overall system costs can be reduced.

Star Semiconductor is also looking to make its name in DSP for commercial applications. Star's edge is its proprietary software, which quickly tunes Star's DSP processors for specific applications without the expensive development effort usually required of DSP designs, says Bob Patterson, vice president of marketing at the Warren, N.J.-based company. □



MARKETS

8-bit embedded controllers have lots of life left

	Worldwide revenue (\$ millions)					6-year CAGR*
	1991	1992	1993	1994	1995	
4-bit	\$739.5	\$782.6	\$736.9	\$761.3	\$775.5	1.6%
8-bit	2,942.2	3,370.5	3,864.8	4,323.7	4,658.7	13.5
16-bit	435.6	566.8	741.9	890.9	994.3	32.3
32-bit	440.9	737.8	1,121.9	1,445.5	1,846.5	45.1
Total	4,558.2	5,457.7	6,492.5	7,421.4	8,275.0	16.7

* Compounded annual growth rate

Source: Electronic Trend Publication

to use the RISC techniques common among 32-bit processors and apply them to the low-end devices. Microchip Technology has developed a line of 8-bit controllers that produce 5-MIPS performance at a cost of about \$5 each in volumes of 1,000.

Microchip Technology's PIC line can operate with 200-nanosecond cycle times to provide performance previously unheard of at the 8-bit level, says Ernest Vilicana, director of marketing at the Chandler, Ariz.-based company. Microchip Technology can convert logic equations of multiple programmable logic arrays into a single high-speed controller-based solution that will save space and cost while increasing performance, he says.

Venerable architectures such as Zilog's Z-80 and Motorola's 68000 have become standards, serving as educational exercises for student engineers who have become comfortable writing software to control the processors and designing interfaces for everything from hard-disk controllers to microwave ovens.

"Who would've thought that an architecture like the Z-80 would last for 15 or 20 years?" Magill muses. "We have been able to increase the performance and lower the cost while simultaneously offering designers a software environment with which they're very familiar." According to Magill, 70% to 80% of an embedded-control customer's investment is in software.

Software development is just as important to the embedded-control customer as hardware performance,

confirms Jerry Kirk, president and founder of Microtec Research, a Santa Clara, Calif.-based developer of compilers and debuggers for embedded processing. Writing better code for 4-bit and 8-bit devices can result in higher performance from the same software, he says.

"The most powerful processors often require the most complex software support, but at all levels of performance, quality software and time to market are important," Kirk says. Microtec has made a business out of providing optimized support for standard processors that allows OEMs to add embedded intelligence to their products within tight design cycles.

Hard-disk drives are one fast-



Jerry Kirk, president and founder of Microtec Research

growing embedded application in which software support solves technical and marketing problems, Kirk says. Although 8-bit processing power may be sufficient, the sophisticated analog interface needed requires advanced software and debugging to assure a bug-free drive meets narrow market windows, he adds.

Interestingly enough, software has sparked an interest in DOS compatible 8-bit microprocessors for embedded applications, according to Chips and Technologies, which late last year introduced a single chip PC based on Intel's venerable 8086 processor. Originally targeted at the hand-held computer market, PCchip is finding more acceptance as an embedded processor in applications where DOS compatibility is important.

AN IMPORTANT FEATURE for embedded controller targeted at application-specific niches is the need for user configurability. Hitachi, one of the largest producers of low-end microcontrollers, offers its zero turn-around time ZTAT features on almost all its microcontrollers. ZTAT uses field-programmable read-only memory (ROM) to allow the customer to configure the standard microcontroller for special functions.

Zilog, which also offers configurable memory on its controllers, is taking another tack to provide custom embedded-control solutions. A new 8-bit device from the company offers programmable output drive capability that allows the designer to tune the processors' output to reduce electromagnetic interference by as much as 75%, Magill says.

Zilog's plans for custom solutions will be supported by new investments in ASIC technology and manpower. In April, the company announced that it acquired the assets of Avant Inc., a communications chip design house that Zilog has used in the past to develop custom chips. Bringing the ASIC design resources inside Zilog will make it even easier to configure low-cost, high-performance custom microcontrollers, says Edgar Sack, president and CEO of Zilog. □

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MY VIEW

Customer Delight. TQL and TQC



AT THE RECENT ELECTRO show in Boston, I had dinner with a gent from a midwestern electronics company. We had first met a little over two years ago when his company had just launched a Total Quality Management (TQM) program. He described for me with a great sense of pride the employees' suggestions that had led to over \$400,000 in savings in the first year of the program alone. People at all levels in the organization had taken on the challenge of improving not only the quality of the product but the quality of the relationship with the customer. They had developed a real sense of working together to improve quality, trim costs, and delight customers. And they were able to achieve a real sense of accomplishment. Near the end of our dinner, I asked what lessons he had learned from the experience. There were many, he said. First, he had the absolute conviction that people would respond to the Total Quality challenge if they had leadership from the top and, equally important, leadership from middle management. Cynical middle managers can scuttle even the best-conceived program; leaders can make it happen. Leaders at all levels in the organization. TQL, not TQM. Leadership, not management.

The second lesson he learned was that, given the opportunity to participate in the process, people will rise to the occasion. And, he smiled and observed, "It's just more fun coming to work. We all get lots of positive feedback from management, from each other, and particularly from the field sales folks and customers. Market share, sales, and profits are up." Fun, indeed.

The next day, I had tea with a marketing friend whose company had been one of the early adopters of the practice of Total Quality and a two-time Baldrige entrant. As I described my experience from the night before, he interrupted and shoved a letter into my hand from one of his company's major customers. It set down a brief list of demands that had to be met if my friend's company expected to do business with this customer in the future. In a nutshell, the deal was this: Cut your prices 10%, or take a hike.

My friend was furious. For over five years, his company had worked to help design products with the customer. Worked together evenings and more than a few weekends to help this customer become successful. And what did have to show for it? A form letter demanding a 10% price reduction.

My friend's experience may be an exception to all the talk we hear about supplier and customer partnerships, but I don't think so. There are still plenty of opportunists out there who will milk the supplier relationship for all it's worth and then sell a supplier down the river for a dime.

It's time we launched a TQC program. TQC—for Total Quality Customer.

—Frank Burge, publisher

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